[To follow front End Paper.

JOHN & HENRY GWYNNE, ENGINEERS,

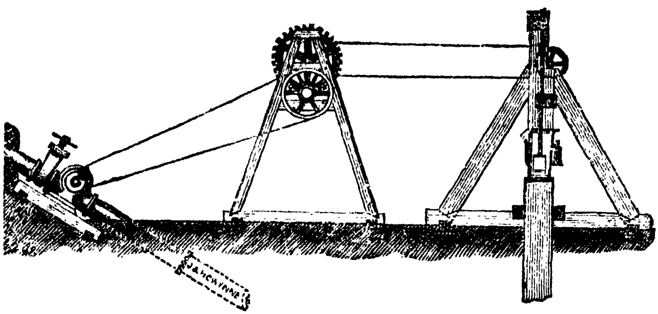
Hammersmith Iron Works, and

89, CANNON ST., LONDON.

"GWYNNE, LONDON."

IMPROVED TURBINE WATER WHEELS

For High and Low Falls, for Working Mining Plant, Pumps, and all kinds of Machinery.

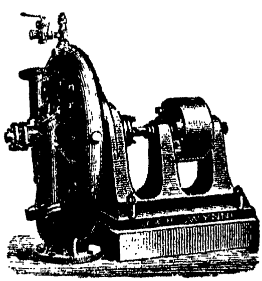


Horizontal-Spindle Turbine Driving Stamps.

"INVINCIBLE" PATENT CENTRIFUGAL PUMPS,

And Direct-Acting Pumping Engines for ALLUVIAL MINES, Washing Ores, &c.

The Cheapest, Simplest, and most EFFICIENT Pumps for moderate Lifts.



Supplied to Gold, Silver, Tin, Copper, and other Mines. Also for Washing Coal, Ore, &c., &c.

[*To face Half Title.*

MINERS' POCKET-BOOK.

[*To face Title.*

MINERS' POCKET-BOOK:

A REFERENCE BOOK

FOR MINERS, MINE SURVEYORS, GEOLOGISTS,

MINERALOGISTS, MILLMEN, ASSAYERS, METALLURGISTS,

AND METAL MERCHANTS, ALL OVER THE WORLD.

C. G. WARNFORD LOCK,

MEMBER OF COUNCIL OF THE INSTITUTION OF MINING AND METALLURGY,
AUTHOR OF 'PRACTICAL GOLD MINING,' ETC.

E. & F. N. SPON, 125, STRAND, LONDON.

NEW YORK: 12, CORTLANDT STREET.

1892.

INTRODUCTION.

WHILST the wants of Civil and Mechanical Engineers are provided for by such handy and valuable works of reference as the "pocket-books" of Molesworth, Hurst, and other well-known authors, the needs of the MINING ENGINEER in the same direction have hitherto been disregarded. Yet, by the nature of his calling the last-named is generally less able to furnish himself with a library, and certainly quite as often is confronted with problems and difficulties, when the means of refreshing the memory with forgotten formulæ or figures is very acceptable.

The preparation of the present little volume has been undertaken with a view of supplying the want, and with a desire to embrace under one pair of covers information on the many and various branches of science with which the Mining Engineer is called upon at times to make himself familiar. Futhermore the economic or commercial side of the industry has not been overlooked, for the ultimate aim of all mining is financial gain.

Obviously it would be impossible to compile such a volume without utilising the published, and in some cases unpublished, work of others; but an endeavour has been made to acknowledge the source of all borrowed statements, except where disclosure has not been desired. This opportunity is taken to publicly thank those whose kind assistance has contributed so much to the value of this pocket-book.

Finally, as it is intended to keep the volume periodically revised nd brought up to date, criticisms and sug[illegible]
will always be gladly taken advantage of.

C. G. WARNFORD LOCK.

15, George Street,
Mansion House, London, E.C.
March 1, 1892.

ILLUSTRATIONS.

THE MINERS' POCKET-BOOK.

MOTIVE POWER.

WORK.

Work is measured by product of the resistance and distance through which its point of application is moved. In performance of work by means of mechanism, work done upon weight is equal to work done by power.

Unit of Work is the *moment* or effect of 1 lb. through a distance of 1 ft., and it is termed a *foot-pound.*

In France a kilogrammetre is the expression, or the pressure of a kilogramme through a distance of 1 metre = 7·233 foot-pounds.

Horse-power.—H.P. is the principal measure of rate at which work is performed. One horse-power is computed to be equivalent to raising of 33,000 lb. 1 ft. high per minute, or 550 lb. per second, or 33,000 foot-pounds of work. It is designated as being Nominal, Indicated, or Actual.

A H.P. in work is estimated at 33,000 lb. raised 1 ft. in a minute but as a horse can exert that force for only 6 hours per day, one work H.P. is equivalent to that of 4·5 horses, at a rate of 3 miles per hour.

Cheval-vapeur of France is computed to be equivalent to 75 kilogrammetres of work per second, or 7·233 foot-pounds, or 75 × 7·233 = 542·5 foot-pounds, which is 1·37 per cent. less than American or English value.

1 kilogrammetre = 7·23314 foot-pounds.
1 foot-pound = 0·138253 kilogrammetre.

MAN POWER. (Haswell.)

Mean effect of power of men working to best practicable advantage, is raising of 70 lb 1 ft. high in a second, for 10 hours per day = 4200 *foot-pounds* per minute.

Windlass.—Two men, working at a windlass at right angles to each other, can raise 70 lb. more easily than one man can 30 lb. *

Labour.—A man of ordinary strength can exert a force of 30 lb. for 10 hours a day, with a velocity of 2·5 ft. in a second = 4500 lb. raised 1 ft. in a minute = ·2 of work of a horse.

Man Power—continued.

A man can travel, without a load, on level ground, during 8·5 hours a day, at rate of 3·7 miles an hour, or 31·45 miles a day. He can carry 111 lb. 11 miles in a day. Daily allowance of water, 1 gal. for all purposes; and he requires 220–240 cub. ft. of fresh air per hour.

A porter going short distances, and returning unloaded, can carry 135 lb. 7 miles a day, or he can transport, in a wheelbarrow, 150 lb. 10 miles in a day.

Crane.—The maximum power of a man at a crane, for constant operation, is 15 lb., exclusive of frictional resistance, which, at a velocity of 220 ft. per minute = 3300 foot-pounds, and when exerted for a period of 2·5 minutes is 17·329 foot-pounds per minute.

Pile-driving.—In average work at a pile-driver, a labourer, for 10 hours, exerts a force of 16 lb., plus resistance of gearing; and at a velocity of 270 ft. per minute, making one blow every 4 minutes.

Drawing or Pushing.—A man drawing a boat in a canal can transport 110,000 lb. for a distance of 7 miles, and produce 156 times the effect of a man weighing 154 lb. and walking 31·25 miles in a day; and he can push on a horizontal plane 20 lb. with a velocity of 2 ft. per second for 10 hours per day.

Pulley.—A man can raise by a single pulley 36 lb., with a velocity of ·8 ft. per second, for 10 hours.

Walking.—A man can pass over 12·5 times the space horizontally than he can vertically, and by walking in alternate directions upon a platform supported on a fulcrum in its centre, he can, weighing 165 lb., produce an effect of 3,984,000 foot-pounds, for 10 hours per day.

Pumping.—A practised labourer can raise, during 10 hours, 1,000,000 lb. water 1 ft. high, with a properly designed and constructed pump.

Crank.—A man can exert on the handle of a screw-jack of 11 in. radius for a short period a force of 25 lb., and continuously 15 lb., a net power of 20 lb. Field's tests gave 11·5 lb. as easily attained, 17·3 as difficult, and 27·6 with great difficulty. Walker gives 13 lb. at a velocity of 320 ft. per minute for 8 hours a day.

MAN'S DAY'S WORK. (D. K. Clark.)

Labourer.—Carrying bricks or tiles, net load 106 lb. = 600 lb. 1 mile.

Carrying coal in a mine, net load 95–115 lb. = 342 lb. 1 mile.

Loading coke into a wagon, net load 100 lb. = 270 lb. 1 mile.

Loading a boat with coal, net load 190 lb. = 1230 lb. 1 mile, or 20 cub. yd. of earth in a wagon.

Breaking 1·5 cub. yd. hard stone into 2 in. cubes.

A man can quarry 5–8 tons of rock per day.

Table 1.—EFFECTIVE POWER OF MEN FOR A SHORT PERIOD.

Manner of Application.	Force.
	lb.
Bench-vice or Chisel	72
Drawing-knife or Auger	100
Hand-plane	50
Hand-saw	36
Screw-driver, one hand	84
Small Screw-driver	14
Thumb and Fingers	14
Windlass and Pincers	60

Smeaton estimates the power of an ordinary labourer at ordinary work as 3762 foot-pounds per minute. In a particular case made by him in the pumping of water 4 ft. high, by good English labourers, their power was equivalent to 3904 foot-pounds per minute.

Table 2.—LABOUR PERFORMED BY A MAN. (Morin.)
For 10 Hours per Day.

Manner of Application.	Power.	Velocity per Second.	Weight raised. Feet per Minute.	H.P. for Period given.
	lb.	ft.	lb.	No.
Throwing earth with a shovel a height of 5 ft.	6	1·33	480	8·7
Wheeling a loaded barrow up an inclined plane, 1 to 12	132	·625	4,950	90
Raising and pitching earth in a shovel 13 ft. horizontally	6	2·25	810	14·7
Pushing and drawing alternately in a vertical direction	13	2·5	1,950	35·
Transporting weight upon a barrow, and returning unloaded	132	1	7,920	144
For 8 Hours per Day.				
Ascending a slight elevation, unloaded	143	·5	4,290	62
Walking, and pushing or drawing in a horizontal direction	26	2	3,120	45·2
Turning a crank	18	2·5	2,790	39
For 7 Hours per Day.				
Walking with a load upon his back	88	2·5	13,200	160·5
For 6 Hours per Day.				
Transporting a weight upon his back, and returning unloaded	140	1·75	14,700	160·5
Transporting a weight upon his back up a slight elevation, and returning unloaded	140	·2	1,680	19
Raising a weight by his hands	44	·5	1,320	14·4

TO COMPUTE NUMBER OF MEN TO PERFORM WORK UPON A PILE DRIVER.

Rule.—To product of weight to be raised and radius of crank, add friction of wheel, and divide sum by product of power and radius of wheel.

Ex.—How many men are required upon a pile driver, 20 ft. diameter, to raise a weight of 9233·33 lb., crank 9 in. long, weight of wheel and its load estimated at 5000 lb., and friction at ·015?

Weight of a man assumed at 125 lb. Radius of crank ·75 ft.

Effect of a man on a pile driver = 30 lb. at a velocity of 1·3 ft. per second = 1·3 × 60 = 78 *ft. per minute.*

9233·33 × ·75 + 5000 × ·015 = 7000 *lb. resistance of load and wheel*, and $7000 \div \frac{78}{20 \times 3{\cdot}1416} \times 10 \times 30 = 7000$ = *load and weight ÷ product of power increased by its velocity over load, radius of wheel and power* = 7000 ÷ 1·241 × 10 × 30 = 18·8 *men.*

To compute Effective Power of Men in raising Mineral by Windlass.

Rule.—Multiply the unit of work in turning a handle by the period and the number of men, and divide the result by the depth in ft. multiplied by the lb. in a ton.

Ex.—4 men working 8 hours a day drawing mineral from a depth of 25 ft. with a common windlass: how many tons will they raise? *Ans.*

$$\frac{4 \text{ men} \times 8 \text{ hours} \times 60 \text{ minutes per hour} \times 2600 \text{ units of work per minute}}{25 \text{ ft. deep} \times 2240 \text{ lb. in a ton}} = 88\tfrac{3}{4} \text{ tons.}$$

To find the Number of Men required to raise a Specific Quantity.

Rule.—Multiply the quantity in tons by the lb. in a ton, by the depth in ft., and divide the result by the number of times, multiplied by the minutes per hour, multiplied by the unit of work.

Ex.—To raise 88¾ tons per day of 8 hours from a depth of 25 ft., how many men required? *Ans.*

$$\frac{88\tfrac{3}{4} \text{ tons} \times 2240 \text{ lb.} \times 25 \text{ ft.}}{8 \text{ hours} \times 60 \text{ minutes} \times 2600 \text{ units}} = 4.$$

Excavating. (Fairley.)

A good ordinary labourer can dig and throw out into a barrow, per day of 10 hours:—

8–10	cub. yd.	common ground.
6	„	firm gravel or stiff clay.
3–5	„	when so hard as to need picking.

ANIMAL POWER.

Results of observations upon animal power furnish the following as maximum daily effects:—

1. When effect produced varies from ·2 to ·33 of that which can be produced without velocity during a brief interval.

2. When the velocity varies from ·16 to ·25 for a man, and from ·08 to ·066 for a horse, of the velocity of which they are capable for a brief interval, and not involving any effort.

3. When duration of the daily work varies from ·33 to ·5 for a brief interval, during which the work can be constantly sustained without prejudice to health of man or animal; the time not extending beyond 18 hours per day, however limited may be the daily task, so long as it involves a constant attendance.

Table 3.—HORSE POWER.

For 10 Hours per Day. (Morin.)

Manner of Application.	Power.	Velocity per Second.	Weight drawn. Feet per Minute.	H.P. for Period given.
	lb.	ft.	lb.	No.
Drawing a 4-wheeled carriage at a walk ..	154	3	27,720	504
With load upon his back at a walk	264	3·75	59,400	1080
Transporting a loaded wagon, and returning unloaded at a walk..	1540	2	184,800	3360
Drawing a loaded wagon at a walk	1540	3·75	346,500	6300
For 8 Hours per Day.				
Upon a revolving platform at a walk			18,000	260·8
For 4·5 Hours per Day.				
Upon a revolving platform at a trot	66	6·75	26,730	218·7
Drawing an unloaded 4-wheeled carriage at a trot..	97	7·25	43,195	353·5
Drawing a loaded 4-wheel carriage at a trot..	770	7·25	334,950	2741

If traction power of a horse, when continuously at a walk, is equal to 120 lb., and grade of road 1 in 30, resistance on a level being one-thirtieth of load, he can draw a load of $120 \times 30 \div 2 = 1500$ lb.

Daily Work in France. (Charié-Marsaines.)

Average daily work of a Flemish horse in North of France, where country is flat and loads heavy, is:—

$$\left.\begin{array}{l}\text{Winter, } 21 \cdot 82 \text{ ton-miles per day} \\ \text{Summer, } 27 \cdot 82 \quad ,, \qquad ,,\end{array}\right\} \text{Mean for the year, 25.}$$

Greatest mechanical effect of an ordinary horse is produced in operating a gin or drawing a load on a railroad, when travelling at rate of 2·5 miles per hour, where he can exert a tractive force of 150 lb. for 8 hours per day.

Tractive Power.

At a speed of 10 miles per hour on a turnpike road, a horse will perform 13 miles per day for 3 years. In ordinary staging, a horse will perform 15 miles per day.

Assuming maximum load that a horse can draw on a gravel road as a standard, he can draw:—

On best broken-stone road	2 to 3 times.
On a well-made stone pavement ..	3 to 5 ,,
On a stone trackway	7 to 8 ,,
On plank road	4 to 12 ,,
On a railway	18 to 20 ,,

Loads.

Assuming load that a horse can draw on a level at 100, he can draw upon inclinations as follows:—

1 in 100	91	1 in 60	85	1 in 30	70
1 ,, 90	90	1 ,, 50	82	1 ,, 25	64
1 ,, 80	89	1 ,, 45	80	1 ,, 20	55
1 ,, 75	88	1 ,, 40	77	1 ,, 15	40
1 ,, 70	87	1 ,, 35	74	1 ,, 10	10

On his back a horse can carry 220–390 lb., or about 27·5 per cent. of his weight.

A draught-horse can draw 1600 lb. 23 miles a day, weight of carriage included.

Ordinary work of a horse may be stated at 22,500 lb. raised 1 ft. in a minute for 8 hours per day.

In a mill, he moves at rate of 3 ft. in a second. Diameter of track should not be less than 25 ft.

A horse weighing 1232 lb. can draw a canal-boat at a speed of 2·5 miles per hour, with a power of 108 lb., 20 miles per day. This is equivalent to a work of 23,760 foot-pounds per minute.

From results of trials upon strength and endurance of horses at Bedford, it was determined that a good horse can draw 1 ton at rate of 2·5 miles per hour, 10–12 hours per day.

Table 4.—Labour a Horse of Average Strength is capable of performing, at Different Velocities, on Canal, Railroad, and Turnpike. (Traction estimated at 83·3 lb.)

Velocity per Hour.	Duration of Work.	Useful Effect, drawn 1 mile.		
		On a Canal.	On a Railroad.	On a Turnpike.
miles.	hours.	tons.	tons.	tons.
2·5	11·5	520	115	14
3	8	243	92	12
4	4·5	102	72	9
5	2·9	52	57	7·2
6	2	30	48	6
7	1·5	19	41	5·1
8	1·125	12·8	36	4·5
10	·75	6·6	28·8	3·6

Animal Power—continued.

Actual labour performed by horses is greater, but they are injured by it.

Tractive Power of a horse decreases as his speed is increased, and within limits of low speed, or up to 4 miles per hour, it decreases nearly in an inverse ratio.

Tractive Power. (Wood.)

To find useful work of a horse. *Rule.*—Multiply the number of trips by distance of trip in miles and by weight in tons of each trip = tons drawn 1 mile per diem.

A horse is capable of exerting a force of 120 lb. travelling at the rate of 2–3 miles an hour, and continuing for 10 hours, or for 20 miles per diem. Thus—

$$\frac{3 \text{ miles per hour} \times 5280 \text{ ft. in a mile}}{60 \text{ minutes in an hour}} = 264,$$

$$264 \times 120 \text{ lb. force} = 31{,}680 \text{ foot-pounds.}$$

Examples of work to be done.—(1) Assuming the horse-power at 120 lb., how many cars weighing $2\frac{1}{4}$ cwt. (252 lb.) each can a horse draw on a tramway rising 1 in 120 and taking the friction at $\frac{1}{65}$? *Ans.*

$$(252 \text{ lb.} \times \tfrac{1}{120} =)\ 2\cdot1 + (252 \text{ lb.} \times \tfrac{1}{65} =)\ 3\cdot877 = 5\cdot977,$$

120

(2) Assuming a car load to weigh 1600 lb., the line rising 1 in 24, and friction at $\frac{1}{65}$, what force is necessary to draw it? *Ans.*

$$(1600 \text{ lb.} \times \tfrac{1}{24} =)\ 66\cdot66 + (1600 \text{ lb.} \times \tfrac{1}{65} =)\ 24\cdot6 = 91\cdot26$$

foot-pounds.

Mule. (D. K. Clark.)

Load on back, 170–220 lb.; day's work = 6400 lb. 1 mile; 400 lb. at 2·9 miles per hour = 5300 lb. 1 mile, and 330 lb. at 2 miles per hour = 5000 lb. 1 mile.

Upon a revolving platform, at a velocity of 3 ft. per second = 11,880 lb. raised 1 ft. per minute, or 172·2 H.P. for 8 hours per day.

Ass.

Load on back, 176 lb., carried 19 miles, day's work = 3300 lb. 1 mile.

In Syria an ass carries 450–550 lb. grain.

Upon a revolving platform, at a velocity of 2·75 ft. per second = 5280 lb. raised 1 ft. per minute, or 76·5 H.P. for 8 hours per day.

Ox.

An ox, walking at a velocity of 2 ft. in a second (1·36 miles per hour), exerts a power of 154 lb. = 18,480 lb. raised 1 ft. per minute, or 268·8 H.P. for 8 hours per day.

A pair of well-conditioned bullocks in India have performed work = 8000 foot-pounds per minute.

WIND POWER.

The altitude or head of the atmosphere at uniform density will be the altitude of a column of water 33·95 ft., divided by the specific gravity of the air, 0·0012046, or,

$$\overline{0\cdot 0012046} = 28,183 \text{ ft.}$$

The velocity due to this head will be—

$V = 8\cdot 02\sqrt{28,183} = 1346\cdot 4$ ft. per second, the velocity with which the air will pass into a vacuum.

When air passes into an air of less density, the velocity of its passage is measured by the difference of their density.

H and h = density of the air in inches of mercury; t = temperature at the time of passage; and V = velocity of the wind in ft. per second.

$$V = 1346\cdot 4\sqrt{\frac{H-h}{h}}\left(1 + 0\cdot 00208\,t\right).$$

The force of wind increases as the square of its velocity.

a = area exposed at right angles to the wind in sq. ft.; F = force of the wind in lb.; H = horse-power, and v = velocity of the plane **a** in direction of the wind, + when it moves opposite, and − when it moves with the wind.

$$F = 0\cdot 002288\,\mathbf{a}\,V^2, \qquad \text{when } v = o.$$

$$F = 0\cdot 002288\,\mathbf{a}\,(V \pm v)^2 \qquad H = \frac{\mathbf{a}\,v\,(V \pm v)^2}{240,384\cdot 6}.$$

Ex.—A rail-train running E.N.E. 25 miles per hour exposes a surface of 1000 sq. ft. to a pleasant brisk gale N.E. by E. Required the resistance to the train in the direction it moves, and the horse-power lost.

E.N.E. − N.E. by E. = 3 points = 33° 45′; V = 14 ft. per second, a brisk gale; $v = 25 \times 1\cdot 467 = 36\cdot 6$ ft. per second, and $F = 0\cdot 002288$ sin. $^2 33° 45' \times 1000$ (14 + cos. 33° 45′ × 36·6)^2 = 305·1 lb.

$$305\cdot 1 \times 36\cdot 6$$

. (Nystrom.)

Table 5.—*Velocity and Force of Wind in lb. per sq. in.* (Nystrom.)

Miles per Hour.	Ft. per Second.	Force per sq. ft., lb.	Common Appellations of the Force of Winds.	Miles per Hour.	Ft. per Second.	Force per sq. ft., lb.	Common Appellations of the Force of Winds.
1	1·47	0·005	Hardly perceptible.	18	26·4	1·55	Very brisk.
2	2·93	0·020	Just perceptible.	20	29·34	1·968	
3	4·4	0·044		25	36·67	3·075	
4	5·87	0·079	Gentle pleasant wind.	30	44·01	4·429	High wind.
5	7·33	0·123		35	51·34	6·027	
6	8·8	0·177		40	58·68	7·873	
7	10·25	0·241		45	66·01	9·963	Very high.
8	11·75	0·315		50	73·35	12·30	
9	13·2	0·400	Pleasant brisk gale.	55	80·7	14·9	
10	14·67	0·492		60	88·02	17·71	Storm.
12	17·6	0·708		65	95·4	20·85	Great storm.
14	20·5	0·964		70	102·5	24·1	
15	22·00	1·107		75	110	27·7	Hurricane.
16	23·45	1·25		80	117·36	31·49	
				100	140·66	50	Tornado.

WINDMILLS.

To find the angle at which the sail should be inclined to the plane of revolution at any distance from the centre:—

Rule.—Multiply 18 twice by the distance from the centre, divide the product twice by the total radius, and subtract the quotient from 23; the remainder is the inclination in degrees.

Ex.—In a windmill 60 ft. diameter, required the inclination of the sail 20 ft. from the centre.

Here 30 ft. is the total radius, and $\frac{18 \times 20 \times 20}{30 \times 30} = 8$, which, subtracted from 23, gives 15°, the angle of that point.

In a windmill about 60 ft. diameter, the diameter of the middle point of the arm is 30 ft., the circumference of the circle in which that point revolves is 94 ft. and the number of revolutions made a minute, with a 5 mile an hour wind, is $\frac{660}{94}$, about 7. The speed of the extremities of the arms is 1320 ft. a minute, or about 15 miles an hour, or 3 times that of the wind. Under ordinary circumstances the speed of the outer extremities of the arms ranges from 20 to 30 miles an hour. We may assume 30 miles an hour when the wind blows at 10 miles with a pressure of about ½ lb. on the sq. ft. The total surface of the sails unfurled in a mill 60 ft. diameter, is 1250 sq. ft.; we may suppose half lost by furling, leaving 625 sq. ft. effective. As the surface is set obliquely to the wind, the pressure in the direction of motion would be reduced from ½ lb. to about ¼ lb. as a mean over the whole of the arms, giving a total pressure

Windmills—continued.

in the direction of motion of about 90 lb. The mean velocity of the arms is half that of the extreme, 15 miles an hour, or 1320 ft. a minute. We have therefore 90 lb. moving at 1320 ft. a minute, which is equivalent to a force of 90 × 1320 = 118,800 lb. moving at 1 ft. a minute. Therefore the power of this mill is about 3½ horse-power. By doubling the diameter of a mill, we quadruple its power, for we quadruple its effective surface.

Horse-power and Sail-area. (Molesworth.)

HP = Horse-power.
V = Velocity of wind in ft. per second.
A = Total area of sails in sq. ft.
N = Number of sails.

$$A = \frac{HP\ 1080000}{V^3}.$$

$$HP = \frac{A\,V^3}{1080000}.$$

$$\text{Area of each sail} = \frac{A}{N}.$$

Velocity of tips of sails = 2·6 V, nearly.

Dimensions of Sails. (Molesworth.)

Length of whip	30	ft.
Breadth of base	12	in.
Depth at base	9	„
Breadth at tip	6	„
Depth „	4½	„

Rule for Angles of Sails. (Molesworth.)

A = Angle of the sail with the plane of motion at any part of the sail.
R = Total radius of sail in ft.
D = Distance of any part of the sail from the axis.

$$A = 23^\circ - \frac{18\,D^2}{R^2}.$$

If the radius of the windmill sails be divided into six equal parts, the angles at each of those parts will be as follows, reckoning from the axis:

Distances from axis	$\frac{1}{6}$	$\frac{2}{6}$	$\frac{3}{6}$	$\frac{4}{6}$	$\frac{5}{6}$	tip.
Angle of sail with axis	67½°	69°	71½°	75°	79½°	85°
Angle of sail with plane of motion	22½	21	18½	15	10½	5

Windmills—continued.

Axis of shaft of windmill with horizon = 8° on level ground.
" " " = 15° on high exposed positions.

Breadth of whip at axis = $\frac{1}{30}$ length of whip.
Depth " " = $\frac{1}{40}$ "
Breadth of whip at tip = $\frac{1}{60}$ "
Depth " " = $\frac{1}{80}$ "
Width of sail " = $\frac{1}{3}$ "
divided by the whip in the proportion of 5 to 3, the narrow portion being nearest to the wind.
Width of sail at axis = $\frac{1}{5}$ length of whip.
Distance of sail from axis = $\frac{1}{7}$ "
Cross-bars, 16–18 in. apart.

WATER.

The natural power contained in a fall of water is equal to the weight of the quantity of water passing over per second, multiplied by the vertical space through which it falls.

Let Q be the quantity of water which passes through the orifice a in the time $t = 1$ second, in cub. ft. of 62·5 lb. each. h = the vertical space the water falls; then the value or natural effect of the fall is at the orifice a:

$$P = 62 \cdot 5\ Q\, h,$$

$$\text{But, } Q = 5 \cdot 06\ a \sqrt{h};$$

$$\text{Then we have } P = 315 \cdot 5\ a\, h \sqrt{h}.$$

This will be in horse-power,

$$H = 0 \cdot 573\ a\, h \sqrt{h}, \qquad H = 0 \cdot 1136\ Q\, h,$$

$$h = 1 \cdot 14 \sqrt[3]{\frac{H^2}{a^2}}, \qquad h = \frac{H}{0 \cdot 1136\ Q}.$$

Ex.—If a creek passes 18 cub. ft. of water per second, how high must that creek be dammed up to produce an effect of 10 horses?

$$h = \frac{10}{0 \cdot 1134 \times 18} = 4 \cdot 9 \text{ ft.} \quad \text{(Nystrom.)}$$

WATER-WHEELS.

Power.—The gross power of a water-wheel is found by multiplying the weight P of the volume furnished by the stream in a second by the height H of the fall. Dividing this product by 75 kilogram-metres (the work corresponding to 1 H.P.) we get the gross power F expressed in horse-power,

$$F = \frac{P\,H}{75}.$$

Table 6.—*Comparison of Columns of Water in ft., mercury in in., and pressure in lb. per sq. in.* (Nystrom.)

lb.	Water.	Mercury.	Water.	Mercury.	lb.	Mercury.	Water.	lb.
per sq. in.	ft.	in.	ft.	in.	per sq. in.	in.	ft.	per sq. in.
1	2·311	2·046	1	0·8853	0·4327	1	1·1295	0·4887
2	4·622	4·092	2	1·7706	0·8654	2	2·2590	0·9775
3	6·933	6·138	3	2·6560	1·2981	3	3·3885	1·4662
4	9·244	8·184	4	3·5413	1·7308	4	4·5181	1·9550
5	11·555	10·230	5	4·4266	2·1635	5	5·6476	2·4437
6	13·866	12·227	6	5·3120	2·5962	6	6·7771	2·9325
7	16·177	14·322	7	6·1973	3·0289	7	7·9066	3·4212
8	18·488	16·368	8	7·0826	3·4616	8	9·0361	3·9100
9	20·800	18·414	9	7·9680	3·8042	9	10·165	4·3987
10	23·111	20·462	10	8·8533	4·3273	10	11·295	4·8875
11	25·442	22·508	11	9·7386	4·7600	11	12·424	5·3762
12	27·733	24·554	12	10·624	5·1927	12	13·554	5·8650
13	30·044	26·600	13	11·509	5·6255	13	14·683	6·3537
14	32·355	28·646	14	12·394	6·0582	14	15·813	6·8425
15	34·666	30·692	15	13·280	6·4909	15	16·942	7·3312
16	36·977	32·738	16	14·165	6·9236	16	18·072	7·8200
17	39·288	34·784	17	15·050	7·3563	17	19·201	8·3087
18	41·599	36·830	18	15·936	7·7890	18	20·331	8·7975
19	43·910	38·876	19	16·821	8·2217	19	21·460	9·2862
20	46·221	40·922	20	17·706	8·6544	20	22·590	9·775
21	48·532	42·968	21	18·591	9·0871	21	23·719	10·264
22	50·843	45·014	22	19·477	9·5198	22	24·849	10·752
23	53·154	47·060	23	20·362	9·9525	23	25·978	11·241
24	55·465	49·106	24	21·247	10·385	24	27·108	11·730
25	57·776	51·152	25	22·133	10·818	25	28·237	12·219
26	60·087	53·198	26	23·018	11·251	26	29·367	12·707
27	62·398	55·244	27	23·903	11·683	27	30·496	13·196
28	64·709	57·290	28	24·789	12·116	28	31·626	13·685
29	67·020	59·336	29	25·674	12·549	29	32·755	14·174
30	69·331	61·386	30	26·560	12·981	30	33·885	14·662

Water—continued.

The effective power of the mill depends solely upon the kind of motor adopted: it is the product of the gross power by the useful effect K of the motor:—

$$\text{Effective power } F\,c = K\,\frac{P\,H}{75}.$$

It is therefore necessary in each particular case to choose the motor best adapted to the conditions of fall and volume in the stream to be used.

WATER: *Turbines, proportions.* (Cullen.)

Q The quantity of water in cub. ft. per second.

H The height of the waterfall in ft.

P The H.P. of the water at 75 per cent. .. $= \frac{Q\,H}{700}$.

d The inner diameter of the wheel .. .. $= \sqrt{\frac{Q}{\sqrt[3]{H}}} + \cdot 1$.

N The number of buckets .. .. $= d \times 3 + 28$.

B The breadth of shrouding .. .. $= \frac{d \times 55}{N}$.

s The shortest distance between two buckets $= \frac{B}{4 \cdot 5}$.

D The external diameter to point of buckets $= B \times 2 + d$.

A The sectional area in inches between all the buckets .. .. $= \frac{Q \times 60}{\sqrt{H} \times 2 \cdot 18}$.

h The height of buckets .. .. $= \frac{A}{N\,S}$.

b The breadth of rim for directors .. .. $= S \times 2 \cdot 8$.

r The radius for centre of directing channels $= D \times 3 \cdot 6$.

v The velocity of inner circumference for low falls .. .. $= \sqrt{H} \times 4 \cdot 4$.

V The velocity of inner circumference for high falls .. .. $= \sqrt[3]{H} \times 8 \cdot 1$.

R The revolutions of wheel per minute .. $= \frac{V \times 60}{d \times \frac{22}{7}}$.

U The diameter of turbine shaft in inches .. $= \sqrt[3]{\frac{P \times 240}{R}}$.

Water—continued.

Note.—$A = \dfrac{Q \times 60}{\sqrt{H} \times 2 \cdot 18}$ for high falls; but $A = \dfrac{Q \times 60}{2 \cdot 08}$ for falls under 38 ft. Power is gained by extending the shroud about $\frac{1}{8}$ its breadth past the buckets when the water leaves them.

To find the Power of the Wheel at 75 per cent.—The cub. ft. of water passing through the wheel per minute, multiplied by the height of the waterfall, and divided by 700, will show by the quotient the power of the wheel. Thus, given 100 cub. ft. of water per second on a waterfall of 9 ft., required the proportions for a turbine in accordance with the foregoing rules, to be driven by 50 cub. ft., and 25 occasionally, and at the time of working with these supplies to produce at least 75 per cent. of useful effect:—

$$\sqrt[2]{\frac{Q}{\sqrt[8]{H}}} + \cdot 1 = 7 \cdot 03 \text{ ft., the interior diameter.}$$

$$d \times 3 + 28 = 49, \text{ nearest number of buckets.}$$

$$\frac{d \times 55}{N} = 7 \cdot 89 \text{ in., breadth of shrouding to point of buckets.}$$

$$\frac{B}{4 \cdot 5} = 1 \cdot 753 \text{ in., shortest distance between two buckets.}$$

$$B \times 2 + d = 8 \cdot 345 \text{ ft., exterior diameter.}$$

$$\frac{Q \times 60}{\sqrt{H} \times 2 \cdot 08} = 961 \cdot 53 \text{ in., sectional area of bucket opening.}$$

$$\frac{A}{N\,S} = 11 \cdot 175 \text{ in., collected height of buckets.}$$

$$S \times 2 \cdot 8 = 5 \cdot 806 \text{ in., breadth of rim of directors.}$$

$$d \times 3 \cdot 6 = 25 \cdot 308 \text{ in., radius for directors.}$$

$$\sqrt{H} \times 4 \cdot 4 = 13 \cdot 2 \text{ ft., velocity of inner circumference.}$$

$$\frac{v \times 60}{d \times \frac{22}{7}} = 34 \cdot 54 \text{ revolutions per minute.}$$

$$\frac{77 \cdot 14 \times 240}{34 \cdot 54} = 8 \cdot 12 \text{ in., diameter of shaft.}$$

$$\frac{11 \cdot 175}{2} = 5 \cdot 5877 \text{ in. high, first tier of buckets to pass 50 ft.}$$

$$\frac{5 \cdot 5877}{2} = 2 \cdot 793 \text{ in. high for second and third tiers, each to pass 25 ft.}$$

Water—continued.

Or, required the number of cub. ft. of water per minute, and all the other dimensions necessary to construct a turbine that will have 34 H.P. on a waterfall of 99 ft. 2 in.:—

$$\frac{34 \times 700}{99 \cdot 16} = 240 \text{ cub. ft. of water per minute, or 4 per second.}$$

$$\sqrt{\frac{Q}{\sqrt[3]{H}}} + \cdot 1 = 1 \cdot 029 \text{ ft., the interior diameter.}$$

$$d \times 3 + 28 = 31, \text{ nearest number of buckets.}$$

$$\frac{d \times 55}{N} = 1 \cdot 826 \text{ in., breadth of shrouding.}$$

$$\frac{B}{4 \cdot 5} = \cdot 406 \text{ in., shortest distance between two buckets.}$$

$$B \times 2 + d = 1 \cdot 333 \text{ ft., exterior diameter to point of buckets.}$$

$$\frac{Q \times 60}{\sqrt{H} \times 2 \cdot 18} = 11 \cdot 06 \text{ sq. in., sectional area of openings between buckets.}$$

$$S \times 2 \cdot 8 = \cdot 9288 \text{ in. for rim of directors.}$$

$$\frac{A}{N\,S} = \cdot 888 \text{ in., height of buckets.}$$

$$d \times 3 \cdot 6 = 3 \cdot 694 \text{ in., radius of directors.}$$

$$\sqrt[3]{H} \times 8 \cdot 1 = 37 \cdot 473 \text{ ft., velocity of inner circumference.}$$

$$\frac{v \times 60}{d \times \frac{22}{7}} = 715 \cdot 49 \text{ revolutions per minute.}$$

$$\sqrt[3]{\frac{34 \times 240}{715 \cdot 49}} = 2\tfrac{1}{4} \text{ in., diameter of shaft.}$$

In simpler terms, the height of the fall in ft. multiplied by the number of cub. ft. of water per minute, divided by 706, will give the actual brake H.P. The H.P. required multiplied by 706, and divided by the height of the fall in ft., will give the number of cub. ft. of water required per minute. When the available quantity of water and the requisite H.P. are determined, the H.P. multiplied by 706, and divided by the quantity of water in cub. ft. per minute, will give the height of fall in ft. that will be required to produce the H.P. It must be remembered that these rules are based upon 75 per cent. efficiency. But when overshot water-wheels are used, the factor 706 must be altered to 815; or allowing only for 65 per cent., which is as much as can safely be relied upon, after deducting the loss of power in gaining speed by means

Water—continued.

of heavy gearing wheels. A good turbine will give 75 to 80 per cent., but in practice nothing more than 75 per cent. should be depended upon.

The old-fashioned water-wheel is, at best, clumsy and cumbrous, but in cases where the fall is less than 20–25 ft., it may be used, provided there is no scarcity of water, and that the cost of transit of so ponderous a machine is not serious; but the danger of accident to the gearing wheels, and the wear of bearings, render it out of place in most instances. It is very largely superseded by turbines, which are so much lighter, and which make so much better use of the water.

WATER: *Turbines.*

Table 7.—*Water required (in cub. ft. per minute)* for various powers under various heads.

	Horse Power.									
	8	10	15	20	30	40	50	60	70	80
3 ft. fall ..	1883	2353	3530							
4 „ ..	1412	1765	2648	3530						
6 „ ..	941	1176	1765	2353	3530					
8 „ ..	706	883	1324	1765	2648	3530				
10 „ ..	565	706	1059	1412	2118	2824	3530			
12 „ ..	471	588	883	1176	1765	2353	2940	3530		
15 „ ..	377	471	706	942	1412	1884	2353	2824	3295	
20 „ ..	282	353	530	706	1059	1412	1765	2118	2471	2824
25 „ ..	226	282	424	565	847	1130	1412	1694	1977	2260
30 „ ..	189	236	353	471	706	942	1176	1412	1648	1883
35 „ ..	161	202	303	403	606	806	1010	1212	1412	1612
40 „ ..	141	176	265	353	530	706	883	1059	1235	1412
45 „ ..	125	157	235	314	471	628	784	941	1098	1255
50 „ ..	113	141	212	282	423	565	706	847	988	1130
60 „ ..	94	118	176	235	353	471	588	706	824	942
70 „ ..	81	101	151	202	303	403	505	606	706	807
80 „ ..	71	88	132	176	265	353	441	530	618	706
100 „ ..	56	71	106	141	212	282	353	424	494	565

The efficiency is calculated at 75 per cent.

Table 8.—WATER: *Measures.*

1 cub. in. fresh water = ·03621 lb.; cub. in. × ·00360 = gallons.

1 „ ft. „ = 6·24 Eng. gal., or 6·32 U.S. gal., or 62·425 lb., or ·557 cwt., or ·028 ton. Cub. ft. × 6·232 = gallons; or × 62·35 = lb.; or × 35·92 tons.

Water—continued.

1 cub. in. sea water	= 64·11 lb.; weight of sea water = 1·027 of fresh water.
1 „ „ ice	= 57·3 lb.
1 „ yd. fresh water	= 1682·5 lb.
1 Eng. gal. „	= 10 lb., or ·16 cub. ft., or 4·543 litres; gallons × ·16045 = cub. ft., or × 277·274 = cub. in., or × ·0044 = tons.
1 lb. „	= ·01607 cub. ft., or ·1 gal.; lb. × ·01607 = cub. ft.
1 cwt. „	= 1·8 cub. ft., or 11·2 gal.
1 ton „	= 35·9 cub. ft., or 224 gal.; tons × 223·897 = gallons, or × ·02783 = cub. ft.
1 litre „	= 61 cub. in., or ·0353 cub. ft., or ·22 gal.
1 kilo „	= 2·204 lb.
1 cub. metre „	= 1000 kilo., or 1000 litres, or 3531 cub. ft., or 1·308 cub. yd., or 220 gal., or 1 ton approximately.
A column „	= a pressure in lb. per sq. in. = half the height in ft.; or 1 ft. high = ·434 lb. per sq. in.; or 1 lb. per sq. in. = column 2·31 ft. high.

Rainfall in inches × 2,323,200 = cub. ft. per sq. mile, or × 14½ = millions of gal. per sq. mile.

P = Pressure in lb. per sq. in.
H = Head of water in ft.
V = Theoretical velocity in ft. per second.
g = Force of gravity.

$P = H \times \cdot 4335.$ $\qquad H = P \times 2\cdot 307.$

Pressure per sq. ft. = H 62·4.

$g = 32\cdot 2.$ $\qquad 2g = 64\cdot 4.$ $\qquad \sqrt{2g} = 8\cdot 025.$

$V = \sqrt{2g}H = 8\cdot 025\sqrt{H}.$

$H = \frac{V^2}{2g} = \cdot 0155\,V^2.$ $\qquad \frac{1}{2g} = \cdot 0155.$

WATER SUPPLY, *calculating*. (Stone.)

The water supplied to miners from the races of the Victoria Government is given in three ways:—(*a*) Through a gauge box, with a pipe of a length equal to two diameters attached. (*b*) Through a siphon pipe from the channel. (*c*) Through a sluice-gate opening of known dimensions, and with a stated head kept on it. The modes of calculating the quantity of water passed for these three different methods are as follows. (Stone.)

For calculating the quantity of water passed through a short

Water—continued.

pipe of two diameters, with square edges, attached to a box, the following formula may be used :—

$$G = \sqrt{H} \times d^2 \times 13,$$

which, when the diameter is required, may be stated

$$d = \sqrt{\left(\frac{G}{\sqrt{H} \times 13}\right)},$$

and when the head is required,

$$H = \left(\frac{G}{d^2 \times 13}\right)^2,$$

where

G = gal. per minute;
H = head in ft.;
d = diameter in in.

The table on p. 22 is calculated from this rule, and can be extended as follows, this extension being based on one of the laws which govern pipes.

Rule.—The discharge of any pipe or series of pipes is proportional to the square root of the head when the length and diameter are constant; therefore, supposing we wanted the discharge through a 4-in. pipe with 4 ft. head, we have by the table for 1 ft. head 208 gal. per minute; therefore, for 4 ft. head the discharge will be

$$\text{As } \sqrt{1} : \sqrt{4} :: 208 : 416 \text{ gal. per minute.}$$

By logarithms.

Log of 4 =	0·6020600
Log of 1 = 0·0000000 ÷ 2	0·3010300
÷ 2 = 0·0000000 log of 208 =	2·3180633
	2·6190933
Log $\sqrt{1}$ =	0·0000000
	2·6190933
Number corresponding to log	416

2. In calculating the quantity of water passed through a siphon pipe, three things should actually enter into the calculation :—

1st. The head due to velocity of entry.
2nd. The head due to the bend at the top.
3rd. The head due to friction in the pipe.

But as the formula for obtaining the second is very complicated, and as if a large radius is given to the bend it does not make

Water—continued.
much difference in the practical result, it may be omitted by the practical miner.

For the first head we shall have, therefore,

$$H = \left(\frac{G}{d^2 \times 13}\right)^2$$

and for the third

$$H = \frac{G^2 \times L}{(3 \times d)^5}.$$

Taking the siphon, we will assume at first that the discharge will be 100 gal. per minute; therefore, neglecting the bend,

For velocity of entry.

Head in ft. required.

$$\left(\frac{100}{2 \cdot 75^2 \times 13}\right)^2 = 0 \cdot 01034$$

For friction.

$$\frac{100^2 \times 22}{(3 \times 2 \cdot 75)^5} = 5 \cdot 75640$$

Total head .. .. .. 5·76674

By logarithms.

Log of 100 =	2·0000000	Log of 2·75 =	0·4393327
Log of $2 \cdot 75^2 \times 13$ =	1·9926088	× 2	2
	0·0073912		0·8786654
× 2	2	× 13	1·1139434
	0·0147824		1·9926088
Number corresponding	·01034		
Log of 100 =	2·0000000	Log of 2·75 =	0·4393327
× 2	2	„ „ 3 =	0·4771213
	4·0000000		0·9164540
× 22	1·3424227	× 5	5
	5·3424227		4·5822700
Log of $(3 \times 2 \cdot 75)^5$ =	4·5822700		
	0·7601527		
Number corresponding	5·7564		

Water—continued.

Then by the rule before mentioned we have

	Gal. per minute required.
As $\sqrt{5\cdot76674} : \sqrt{10} :: 100$:	$131\cdot68$

By logarithms.

	Log of 10 =	1·0000000
	÷ 2	0·5000000
	× 100	2·0000000
Log of 5·76674 = 0·7609274		2·5000000
For square root ÷ 2 = 0·3804637		0·3804637
		2·1195363
	Number corresponding to log	131·68

The discharge through the siphon pipe is therefore, neglecting the bend at the summit, nearly 132 gal. per minute if it is wished to include the bend; if the head required for the bend were added, if it is of a *large radius* the difference would be practically nothing, but if of small radius it should be added, as it would reduce the discharge.

3. In calculating the quantity of water passed through a sluice *gate* with side walls, the formula to be used for obtaining the number of gal. per minute with a given head and opening is

$$G = 8\cdot025 \times \sqrt{H} \times \cdot6 \times A \times 6\cdot23 \times 60,$$

and for the head required on a certain opening to give a certain discharge,

$$H = \left\{\frac{\left(\frac{G}{6\cdot23 \times 60} \div A\right) \div c}{8\cdot025}\right\}^2.$$

Ex.—What will a sluice gate opened 1 ft. and 3 ft. wide discharge with a head to the *centre* of the orifice of 1 ft.? By the formula

$$8\cdot025 \times \sqrt{1} \times \cdot6 \times 3 \times 6\cdot23 \times 60 = 5399\cdot54 \text{ Gal. per minute.}$$

8·025	14·4450
1	6·23
8·025	433350
·6	288900
4·8150	866700
3	89·992350
14·4450	60
	5399·541000

or a little over 5399½ gal. per minute.

Water—continued.

If the head had been required to pass 5399·54 gal. per minute through a sluice opening of 1 ft. × 3 ft.

By formula

$$\left\{\frac{\left(\frac{5399\cdot54}{6\cdot23\times60}\div \mathrm{A}\right)\div c}{8\cdot025}\right\}^2 = 1 \text{ ft.}$$

```
   6·23
     60
 ------
 373·80)5399·54(14·445
         37380
         ------
         166154
         149520
         -------
          166340
          149520
          -------
           168200
           149520
           -------
            186800
            186900
```

```
      3)14·4450
        -------
      ·6)4·8150
 8·025)8·025
        -----
        1·000
```

and the square of 1 is 1; therefore the head required is 1 ft.

The water may occasionally be supplied from a *sluice* valve, and then the following formulæ are applicable, assuming that a length of pipe of not more than 2 to 3 diameters is attached to it, for if more pipe is attached, then the friction in the pipe also must be taken into account. Assuming, therefore, that the pipe is not longer than twice or three times the diameter of the *sluice* valve, we may use

$$\mathrm{G} = \sqrt{\mathrm{H}} \times d^2 \times 10$$

$$\mathrm{H} = \left(\frac{\mathrm{G}}{d^2 \times 10}\right)^2$$

$$d = \sqrt{\left(\frac{\mathrm{G}}{\sqrt{\mathrm{H}} \times 10}\right)}.$$

Ex.—What is the discharge of a *sluice* valve 4 in. diameter with a head on the *centre* of the valve of 1 ft.? By the formula

$$\begin{aligned} &\sqrt{1} \times 4^2 \times 10 \\ &= 1 \times 16 \times 10 \\ &= 16 \times 10 \\ &= 160 \text{ gal. per minute.} \end{aligned}$$

Water—continued.

If the head is required to discharge 160 gal. per minute, we have

$$\left(\frac{160}{4^2 \times 10}\right)^2$$

$$= \frac{160}{160} = 1 \text{ ft.}$$

For *diameter* we have

$$\sqrt{\left(\frac{160}{\sqrt{1} \times 10}\right)}$$

$$= \sqrt{\frac{160}{10}}$$

$$= \sqrt{16} = 4 \text{ in.} \qquad \text{(Stone.)}$$

Table 9.—WATER SUPPLY:

Discharges through a Short Pipe of two Diameters coming from a Box, with a Head on the Centre *of the Pipe* of* 1 *ft.* (Stone.)

Diameter: in.	Discharge: gal. per minute.	Discharge: gal. in 8 hours.	Remarks.
½	3·25	1,560	The head assumed to give the discharge shown is in all cases 1 ft. in this table.
1	13·00	6,240	The discharge for any other head may be found by the rule that the discharge is proportional to the square root of the head.
1½	29·25	14,040	A sluice head in Victoria is equal to about 200,000 gal. in 24 hours, therefore a 4-in. pipe in a box of the description given should have a head of 0·668 ft. or $8\frac{1}{32}$ in. over the *centre* of the pipe to give one "sluice head."
2	52·00	24,960	The head should be measured to still water—or an addition made for velocity of approach.
2½	81·25	39,000	
3	117·00	56,160	
3½	159·25	76,440	
4	208·00	99,840	
4½	263·25	126,360	
5	325·00	156,000	
5½	393·25	188,760	
6	468·00	224,640	
6½	549·25	263,640	
7	637·00	305,760	
7½	731·25	351,000	
8	832·00	399,360	
8½	939·25	450,840	
9	1053·00	505,440	
9½	1173·25	563,160	
10	1300·00	624,000	
10½	1433·25	687,960	
11	1573·00	755,040	
11½	1719·25	825,240	
12	1872·00	898,560	

* This pipe is supposed to be horizontal.

WATER: *Miners' "inch."*

The "miners' inch" is an arbitrary measure of the quantity of water which will flow through a given space in a given time, adopted in the early days of American gold-mining, and established by the law of each miners' camp, without any attempt at a universal scale. Thus there are scarcely two localities where the miners' inch has the same signification, the size and shape of the outlet and the manner of discharging the water varying constantly.

The most common way of estimating the "inch" is the amount of water which will pass through an opening 1 in. square in a plank 2 in. thick, with a pressure of 6 in. above the opening or 7 in. over the centre. The thickness of the plank is sometimes 3 in. The lower front end of the discharge is usually chamfered. Raymond says that with an aperture of 1 sq. in. and a pressure of 6 in., the "inch" will equal 94·7 cub. ft. per hour. In other localities the pressure used is 10 in., making 109·1 cub. ft. per hour. The average Californian miners' "inch" he puts at 100 cub. ft. per hour, or 1000 cub. ft. per day of 10 hours. He adds the following table of the standard miners' inch:—

Pressure from Surface to Top or Middle of Orifice.	Miners' inch.	Cub. Ft. (each 6·23 gal.).				Authority.
		Per Second.	Per Minute.	Per Hour.	Per 24 Hours.	
in.						
6	1	0·039	2·34	140	3,360	Hittell.
,,	1	0·026	1·57	94·7	2,274	Carpenter.
,,	38	1·000	60·00	3600·0	86,400	,,
,,	1000	26¼	1580	94,700	2,274,600	,,
10	1	0·03	1·8	109·1	2,618	,,
6 to 10	1	0·027	1·6	100	2,400	Standard experimental miners' inch.
,,	10	0·27	16	1,000	24,000	
,,	100	2·7	166	10,000	240,000	
,,	1000	27	1666	100,000	2,400,000	

The Milton Co. reckon a flow through an aperture 12 in. wide and 12¾ in. high, when the water stands 6 in. above the top of the opening, as 200 "inches."

Raymond observes that the usual acceptation of the miners' inch is that given by Hittell, and he quotes the following formula from Haswell for making the calculation:—

$$\tfrac{2}{3} b \sqrt{2g} \left(h' \sqrt{h'} - h \sqrt{h}\right) C = V;$$

b being the breadth, h' the distance from the sill to the surface, and h the distance from the top of the opening to the surface in feet,

Water—continued.

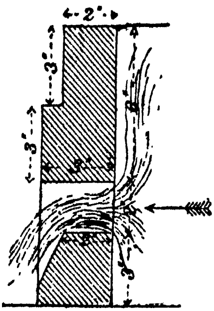
while C is the coefficient of discharge assumed at 0·750, and V the volume in cub. ft. per second; thus—

$$\frac{2}{3}\times\frac{1}{12}\sqrt{2g}\left(\frac{7}{12}\sqrt{\frac{7}{12}}-\frac{6}{12}\sqrt{\frac{6}{12}}\right)\times 0\cdot750 = 0\cdot031 \text{ nearly.}$$

He thinks the coefficient of discharge is perhaps a little too high.

Egleston states that the quantity of water which will flow from an opening 1 in. square will be 93 lb. per minute. The opening, however, is never made 1 in. square, but is always longer or higher, which will necessarily increase the quantity of water which will issue from each sq. in. Thus the quantity of water which is given by a single sq. in. opening will be 93 lb. per minute, and from an opening 1 in. × 2 in. will be 196½ lb., and with 1 in. × 100 in. each inch will pass 111 lb. Sometimes the opening is 2 in. high. At North Bloomfield, it is 48 in. long × 2 in. high, with a pressure of 9 in. above the opening. Each square inch will thus furnish 4252 cub. ft. per 24 hours. At Eureka, the opening is the same, 48 in. × 2 in., with 6 in. pressure above the top of the opening, so that each square inch will furnish 3240 cub. ft. per 24 hours. . . . The La Grange inch is equal to 2·159 cub. ft. To determine the value of the North Bloomfield "inch," the water was made to discharge through a 3-in. plank. The bottom of the opening was above the bottom of the tank holding the water (Fig. 1), and was chamfered off 1 in. from the outside, so that the outside opening was 4 in. high. The value of this "inch" is given in the following table, which shows, according to Bowie, the variations in some of the "inches" and their supply:—

Fig. 1.



Miners' Inch.

Name of Mine.	Height of Opening.	Length of Opening.	Pressure over Centre of Opening.	Quantity discharged by 1 sq. in. per minute.	Quantity discharged in 24 hours.
	in.	in.	in.	cub. ft.	cub. ft.
Smartsville	4*	†	9	1·76	2534·4
Park Mining Co. ..	..	..	..	1·39	..
North Bloomfield ..	2	50	7	..	..
Eureka	2	48	7	..	..

* The bottom of the aperture is on a level with the bottom of the box.

† An opening 250 in. long × 4 in. wide will discharge 1000 Smartsville "inches." The day is usually reckoned as 11 hours.

Water—continued.

	H. Smith, 1874. cub. ft.	A. J. Bowie, 1876. cub. ft.
One miner's in. discharges in 1 second	0·2624	0·2409
" " 1 minute	1·5744	1·4994
" " 1 hour	94·4640	89·9640
" " 24 hours	2267·1360	2159·1460
Ratio of actual to theoretical discharge	61·60 per cent.	59·05 per cent.

Raymond remarks the discrepancies among different companies, thus—

	Height of Aperture.	Pressure.	
Eureka Co.	2 in.	6 in.	The amount delivered by them through 20 in. × 2 in. is considered 40 in.
Excelsior	—	10 "	Measured from centre of orifice.
Sears	—	10 "	Measured from centre of orifice.
Mokelumne	—	4 "	
Campo Seco	—	4 "	
Phœnix	3 in.	4 "	Over the orifice.
Gold Hill	2 "	4 "	An inch wide.
Another	3 "	none	An inch wide.

At Smartsville, water is sold with a head of 9 in., with a 14-in. opening 125 in. long, giving 11·8 per cent. for an "inch" more than is usually given. The quantity discharged through an opening 4 in. deep, with a 9-in. head over the middle of the opening, with the coefficient of discharge = 0·0615 is 106·6 cub. ft. per hour, or 1·7767 cub. ft. per minute. A "head of water" is 500 in. daily for 10 hours, and is the quantity required for a first-class hydraulic operation.

Horse-Power of Miners' inch.—Theoretical horse-power of the miners' "inch" (Egleston):—

Heads in ft.	100	90	80	70	60	50	40
	30	20	15	10	5	3	1
Inches to H.P.	3·25	3·61	4·06	4·64	5·41	6·50	8·12
	10·8	16·2	21·6	32·5	65	108	325

With a moderate ditch delivery of 4000 in., or 5 heads at 800 in., the work done may be 1 cub. chain or 10,000 cub. yd. per day, or in a 10 days' run, an acre 1 chain deep or 100,000 cub. yd. Taking an average of 2000 cub. yd. per day of 10 hours, moved by 300 in. of water, 5 days would move a cub. chain or 10,000 cub. yd.; 800 in. at 100 ft. head working 10 hours = 800 10-ft. cubes of water = 800,000 cub. ft., weighing 24,880 tons, without adding the pressure arising from the head employed. This will move through ordinary sluices, at a grade of 8 to 12 in. per box, 3000 cub. yd. of loosened gravel, or 2000 cub. yd. of ordinary uncemented bank gravel, say an average of 2500 cub. yd., weighing 8300 tons or $\frac{24880}{8347} = \frac{1}{3}$ of the weight of the water employed. Reckoned by "inches," the amount of gravel moved = 3 times as many cub. yd. as there are miners' "inches" used. (Raymond.)

WATER: *Measuring Stream.*

(*a*) The breadth, depth, and velocity of a stream in feet per minute as travelled by a chip, may be estimated by the eye. The sectional area being reduced to sq. ft. and decimals, we have multiple $\times$ 60 = cub. ft. per hour; divided by 100 = miners' "inches." Or, observe 6 seconds, and the distance $\times$ area $\times$ 6 = miners' "inches."

(*b*) If the channel of the stream has a moderately even outline, measure its depth at regular intervals from shore to shore. Add all these depths together, and divide the sum by the number of soundings. An average depth is thus gained. Calculate then the area of the section by the rule for finding area of a section of a flume with straight sides. Measure the velocity by means of a float, and make the test about half way between the bank and the centre. Multiply the area by the velocity, and the product will be the flow. Of course the test for velocity should be made at the same point where the measurements for depth are made, and a place on the stream should be selected for both where the banks are as nearly parallel as may be, and where the current and flow are the most tranquil. *Ex.*—A stream is 24 ft. broad, and 10 soundings at every 2 ft. on a line from bank to bank give 2, 6, 8, 9, 7, 11, 11, 10, 9, and 2 in. as the depths. The average velocity as determined by float is 4 ft. per second. What is the flow? *Ans.*—The sum of the 10 soundings is 75 in., which gives an average depth of 7·5 in., equal to ·625 ft. The area of the section then is 24 multiplied by ·625 = 15 sq. ft. The velocity being 4 ft. per second, the flow is equal to 15 multiplied by 4 = 60 ft. per second. If the stream runs over a bottom so irregular that an average depth cannot be gained, or an average velocity measured, there is no recourse but to construct an artificial channel, having no grade, into which it may be turned while measures are made. (Von Wagenen.)

(*c*) H. T. Turner has lately reviewed the methods used by engineers to estimate the quantity of water (1) when flowing from a state of rest in a pond through an artificial notch, and (2) when flowing in rivers where the stream is greatly disturbed owing to the roughness of the bed. The unit of measurement commonly employed is the cub. ft. discharged per second of time, though for convenience results are often expressed in such derived units as "million gal. per 24 hours."

Notch-gauging, the commonest of all methods of measurement, from the simplicity of the apparatus, observation, and calculation necessary, is applied to ascertaining the flow from a still pond or reservoir, the dimensions of which must be so large relatively to the volume being discharged by the notch, that the water in the neighbourhood of the exit may be in a sensibly statical condition. The form of overfall notch is either rectangular or V-shaped. The plate, usually of metal, which forms the edge of the notch, should be 3–4 in. wide, smooth on the up-stream face, and bevelled away

Water—continued.

at the edges on the down-stream face, so as to present a fairly sharp edge to the flowing stream. The weir, in which the plate is fixed vertically, and on the up-stream side, should extend beyond each end of the notch for a distance not less than 3 times the greatest height of water proposed to be passed over the notch sill, and the depth of water below the sill should also not be less than this. Another important feature is that the surface of the pond on the down-stream side of the notch, into which the water discharges, should be sufficiently below the sill to avoid reduction of the atmospheric pressure on the under side of the stream, through the closing in of the ends and exhausting action of the flowing water. The above precautions are essential to aoccurate notch-gauging, to ensure uniformity of the flow. For its estimation by this method depends mainly upon the results of previous experiment made under such conditions, and it is therefore necessary to observe similarity of conditions in the practical cases to which these results are to be applied.

The rectangular form of notch is used for measuring a fairly constant flow, and the V notch for small and variable flows. In both cases the discharge is the product of the area of the stream in the plane of the notch into its mean velocity past that plane: or $Q = A\,V$.

For the rectangular notch, the ordinary expression for Q, the rate of discharge in cub. ft. per second, is

$$Q = C\,l\,h^{\frac{3}{2}},$$

Where l is the length of notch;
,, h is the height of still-water surface above the notch-sill;
And C is a coefficient determined by experiment.

The truth of the expression depends upon a proper value being assigned to C, to ascertain which many careful experiments have been made. An examination of these shows a striking coincidence in their results when applied to precisely similar conditions, and a general variation of C as $\frac{l}{h}$.

That this coefficient should be some function of $\frac{l}{h}$, would appear evident from the consideration, that whilst the influence of the ends of the notch, termed end-contractions, upon the discharge depend in some manner upon h, their effect relatively to the total discharge must vary inversely as l.

Although the phenomenon has been noticed both by experimenters and by those who have deduced rules for practical use from their results, it has been customary to obtain from each series of experiments a mean coefficient; and as the investigators have

Water—continued.

chiefly confined their experiments to short notches, with consequently but a small range in the values of $\frac{l}{h}$, these mean coefficients do not widely differ from one another:—

Name.	Mean value of C.
Dubuat	3·38
Eytelwein	3·40
Bidone	3·32
Poncelet and Lesbros	3·23
Brindley and Smeaton	3·41
Blackwell	3·37

Now, although most of the above means do not differ very much from any of the actual values of C in each series, when the ratio becomes much greater than its average value in the experimental cases, a serious error is introduced by taking C constant. This, in fact, amounts to the diminution of discharge owing to end-contraction, repeated as many times as the length of the notch under consideration is a multiple of that of the experimental notch. It might be inferred that an extension of the experiments to higher values of $\frac{l}{h}$ would result in higher values of C being obtained; and Blackwell's experiments on a 10-ft. notch confirm this view. He, however, suggested for practical use the mean value $C = 3·380$ for a 3-ft. notch, and $C = 3·570$ for a 10-ft. notch.

Francis avoided the difficulty of introducing a variable coefficient by making the effect of end-contraction a deduction from the full discharge, dependent only upon h, and specifying that the length of the notch shall be always so great in proportion to the head, that the influence of end-contraction shall not be sensible to a greater distance from either end than to the centre of the flow.

His formula for values of h between 2 ft. and 0·5 ft. is

$$Q = 3·33\,(l - n\,0·1\,h)\,h^{\frac{3}{2}},$$

Where n = the number of end contractions. (In the present case two.)

And provided that the ratio $\frac{l}{h}$ never becomes less than 3.

His experiments did not extend to this last-mentioned condition, and Turner questions the propriety of applying the formula to such a low value of $\frac{l}{h}$. In support of this view, the velocity-curve across an 8 ft. rectangular notch under a head of 0·5 ft. was tried. The velocities were measured with an accurately-rated electric current-meter, whose fan traversed the plane of the notch, clearing

Water—continued.

the sill by about $\frac{1}{8}$ in., and being just covered by the water. The velocities appear generally higher on the left than on the right, attributable to the assistance received by the fan, which was a left-hand one, from the side-flow near the left end of the notch, and the resistance to turning experienced near the right end, owing to the velocity being greater in the lower than in the upper half of the depth. But none the less striking is the diminished velocity near each end of the notch, and it may certainly be taken as extending for a distance of 1·5 ft. into the flow from each end. That is, the total length of notch sensibly affected by end contraction under 0·5 ft. head is 3 ft., or six times the head.

The "coefficients of efflux" determined by Poncelet and Lesbros show that the rate of increase of the coefficient diminishes markedly as the value of $\frac{l}{h}$ passes from 5 to 8. And because in every similar notch the conditions of flow are similarly affected, this value $\frac{l}{h} = 6$, as the least allowable, holds for all notches of like character, no matter what value be assigned to h. With these restrictions, Francis's formula must be accepted as the most reliable under ordinary practical conditions yet published.

For long notches discharging under small heads, where the value of $\frac{l}{h}$ is greater than 20, there is, excepting Blackwell's experiments before referred to, no published record of investigation upon the necessary scale to be of use in determining a true expression for discharge. Comparing Blackwell's measurement of the discharge over a 10-ft. notch under a head of 0·16 ft. with that given by the old expression $Q = C\, l\, h^{\frac{3}{2}}$, where the adopted value of C is 3·34, the average of the six mean coefficients before noted, it appears that

Q measured by Blackwell = 2·91 cub. ft. per second;

Q by formula $3 \cdot 34\ l\, h^{\frac{3}{2}}$ = 2·34 „ „

That is, the discharge calculated by the formula falls short of the truth by more than 20 per cent. in this instance. And if the notch were longer, the comparison would be still more unfavourable to the formula.

To meet this difficulty, Turner suggests an expression derived from the following investigation:—Taking the results of Francis's experiments upon a 10-ft. notch, he reduces them to the discharges of a 3-ft. notch under precisely similar conditions of head, and compares these latter quantities with those measured by Blackwell over a 3-ft. notch.

Table 10 shows this comparison.

Table 10.

Francis's Experiments.			Reduction to Discharge over 3-ft. Notch.			Blackwell's Measurement of Discharge (3 ft. Notch.)
Length of Notch.	Head.	Q.	Length of Notch.	Head.	Q.	
ft.	ft.	cub. ft. per second.	ft.	ft.	cub. ft. per second.	cub. ft. per second.
10	1·5	59·30	3	0·45	2·92	2·91
,,	1·0	32·60	,,	0·30	1·61	1·64
,,	0·8	23·40	,,	0·24	1·15	1·18
,,	0·7	19·20	,,	0·21	0·95	0·97
,,	0·6	15·30	,,	0·18	0·75	0·78
,,	0·5	11·70	,,	0·15	0·58	0·60

NOTE.—The values of Q in the last column are obtained from the discharge curve drawn through the points determined by Blackwell's experiments.

The reduction is effected by multiplying Francis's method by $\left(\frac{3}{10}\right)^{\frac{5}{2}}$, according to the method enunciated by Professor J. Thompson. The close coincidence of the two series of results in the sixth and seventh columns of the Table affords evidence of the accuracy of the gaugings.

But applying the method previously noticed, and reasoning from the lower quantities discharged by a 3-ft. notch to those which a 10-ft. notch would discharge under similar conditions of head, the results obtained are as summarised in Table 11.

Table 11.

Discharge of a 3-ft. Notch, obtained from Equation.		Discharge of a 10-ft. Notch under similar Head.		10-ft. Notch. Blackwell's Measurement under this Head.	10-ft. Notch. Discharge by Formula, D'Aubuisson.	10-ft. Notch. Discharge by Formula, Poncelet.
Head.	Q.	Head.	Q.			
ft.	cub. ft. per second.	ft.	cub. ft. per second.	cub. ft. per second.	cub. ft. per second.	cub. ft. per second.
..	..	0·083	..	1·04	..	..
..	..	0·16	..	2·92	..	..
0·083	0·260	0·277	5·27	..	..	..
0·100	0·340	0·3	6·89	6·76	..	..
0·125	0·468	0·417	9·49	9·36	..	..
0·150	0·607	0·5	12·29	..	12·31	12·04

Column 4 gives values of Q obtained as described. Column 5 gives for comparison the available direct measurements on a 10-ft.

Water—continued.

notch (Blackwell's). Columns 6 and 7 give values of Q under a head of 0·5 ft. according to the ordinary formula, using respectively D'Aubuisson's and Poncelet's values of C for this ratio of length to height, being the only other available determinations of the coefficients for so high a ratio.

From the value of Q for any head on the 10-ft. notch (up to $h = 0\cdot5$ ft.) deduct the value of Q for the same head on the 3-ft. notch. One-seventh of this difference is the discharge per lineal ft. of the middle portion of the 10-ft. notch not affected sensibly by end contraction. Thus Q per lineal ft. of notch unaffected by end contraction is

$$\left(\frac{33\cdot15 - 9\cdot13}{7}\right) h^{\frac{10}{7}} = 3\cdot43\, h^{1}$$

However the length of notch be increased for the low heads under consideration (i. e. h less than 0·5 ft.), and when l is not less than 3 ft.

$$Q = (l - 3)\, 3\cdot43\, h^{\frac{10}{7}} \times 9\cdot13\, h^{\frac{10}{7}},$$

cub. ft. discharged per second,

$$- 3\cdot43\, (l - 0\cdot34)\, h^{\frac{10}{7}}.$$

As evidence of the accuracy of the formula, Turner submits the results of three experiments on an 8-ft. notch in Table 12:—

Table 12.

Head.	Measured Discharge over an 8-ft. Overfall Notch.	By Formula. $Q = 3\cdot43\ (l - 0\cdot34)\ h^{\frac{10}{7}}$.	By Formula. $Q = 3\cdot34\, l h^{\frac{3}{2}}$.
ft.	cub. ft. per second.	cub. ft. per second.	cub. ft. per second.
0·563	11·33	11·56	11·29
0·5	9·87	9·88	9·43
0·354	6·09	5·96	5·64

Column 4 shows the deficiency caused by the use of the mean coefficient in this case of high values of $\frac{l}{h}$.

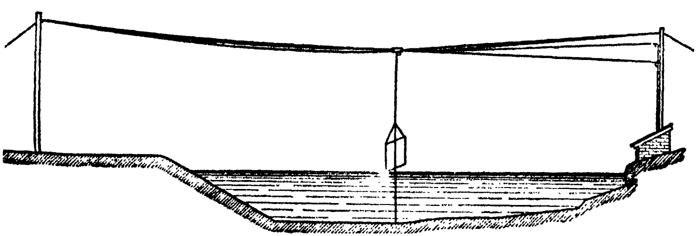
In lower values of h, error in defect, through the use of a mean coefficient, increasing with the value of $\frac{l}{h}$, is noticeable, and cannot be far short of 20 per cent. when $h = 0\cdot2$ ft.

The quantities discharged were computed from velocity observations made in a straight and uniform brick channel that carries the water from the Lower Rivington reservoir to the still pond

Water—continued.
above the notch. An accurately-rated electric current-meter was used, and each experiment comprised a series of twenty velocity measurements in a cross section of about 13 sq. ft. The readings of the meter were taken twice at each point, and before commencing a series it was ascertained that the condition of the channel and pond was permanent. Gauging with the V notch is not attended with the difficulties in computation attached to the rectangular form, and an accurate expression for the discharge is a matter of ordinary hydraulics.

As an example of the most modern method of accurate river-gauging, Turner describes the operation of gauging the flow of the River Severn, in connection with the Liverpool Water Act, for obtaining a new supply from the River Vyrnwy. The site selected was at a point about 1 mile above the Diglis Weir at Worcester, on a straight reach ½ mile in length. The river is here 180 ft. wide, and when bank-full is about 25 ft. deep in the middle. The section having been accurately levelled, two staffs were fixed on opposite sides of the river with their zero points at the level of the lowest dry-weather flow, and the discharges corresponding with different readings of these staff-gauges were computed from velocity measurements made at each foot of depth below the water surface, past verticals 10 or 20 ft. apart in the cross section. These measurements were made with two of Deacon's electric current-meters previously rated. Fig. 2 is a sketch of the apparatus specially

Fig. 2.



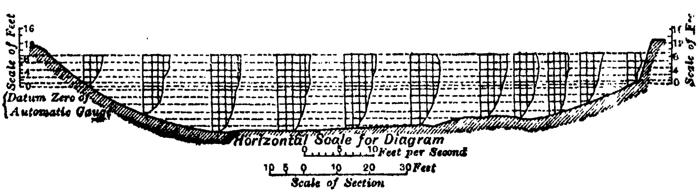
River Severn. Section of River showing Gauging Tackle.

constructed for directing the meters to any position in the river section. It consists of two upright poles, 50 ft. in height, placed 240 ft. apart on opposite sides of the river. Between these poles is stretched tightly a No. 12 steel wire, upon which traverses a small carriage mounted on two 3-in. pulleys; the carriage is moved forwards or backwards by an endless wire passing round pulleys at the head of each pole, and wound upon rollers at the foot of the pole on the east bank. From this carriage is suspended, firmly

Water—continued.

attached to it by means of jaws, a T-shaped frame of ½-in. iron piping pointing up and down stream, and carrying, at each extremity of the T-piece, pulleys, over which pass two other wires attached to a lower bar of the same length as the T-piece. These wires are led over a pulley in the carriage to a roller similar to those previously mentioned. The diameters of the rollers are suitably arranged for paying out standard lengths of wire for a given number of turns. The lower bar carries on its up-stream end a socket into which is fixed a short upright rod, and upon this the current-meters are securely clamped, and by means of the above gear they can be brought into any position in the cross section. A fourth wire passes over a pulley in the carriage, down the inside of the stem of the T, and through the lower bar, and is attached to a cast-iron anchor-plate weighing 70 lb., which rests on the bed of the river. It is armed on the under side with six 3-in. spikes, and its use is to keep the T-frame and lower bar vertically in position during an observation. By means of the last-mentioned wire it is raised when the meters have to be moved on to a fresh vertical. The insulated wires are carried from the meters over the head of the T-frame to a shed where the rollers and electrical apparatus are placed, and in which the operators stand. The method of computing the discharge of the river corresponding with any staff-reading is as follows:—The observed velocities past each vertical are plotted to a large scale on a diagram, so as to form velocity-curves at each point whose areas represent the discharges past the respective verticals. The integration of a complete series of such discharges gives the total corresponding rate of discharge. Fig. 3 shows a diagram of one complete series of observations. Both staff-

Fig. 3.



River Severn. Velocity Observations.

gauges are read regularly throughout each operation, and the mean water-level is carefully determined. The results of observations are plotted to a curve. From this curve is constructed a discharge-scale, giving the rate, in million gallons per day, corresponding with the staff-gauge reading used for computing the

Water—continued.

daily flow of the river from the diagrams of an automatic gauge. These are drawn by a pen whose zero coincides with that of the staff-gauges before mentioned. (H. T. Turner.)

(*d*) Cullen gives the following rules for ascertaining the velocity of water in rivers:—Select a portion of the watercourse where the direction of the running water is as straight as possible. Measure some convenient distance along the stream, say 100 ft.; at the extremities of this length, and at right angles across the stream, fix two straight cords; then get a few floats of hard wood, or well-corked bottles (they should be so weighty that when placed in the water they would not project over it as to be materially affected by the wind). After having these preparations made, the floats are dropped lightly into the current at a little distance above the upper cord, then note the time by a stop-watch that the float takes to pass over the distance between the two cords. This experiment should be repeated several times with floats both in the middle and near the sides of the stream, the arithmetic mean is then taken for the surface velocity of each experiment. Having by these means found the several spaces run over in a given time, the mean proportion of all these trials is taken for the surface velocity of the water. Four-fifths of the surface velocity is a good approximation to take for the mean velocity of the stream, or the velocity it would have supposing all the particles of the stream to have moved in every part of its channel with one uniform motion. If this velocity be multiplied by the breadth and depth of the mass of flowing water, the product will be the number of cub. ft. which passed from one cord to the other during the time of observation. This may be adapted to any other proportion of time. *Ex.*—Required the quantity of water discharged in cub. ft. per minute, in a channel 8 ft. broad, and water 2 ft. deep, supposing the measured distance between two cords placed across the channel to be 100 ft.; and after making 5 different experiments on the time which floats took to pass from one cord to the other, it was found to be as follows:—At the first trial it took $11\frac{1}{2}$ seconds; at the second, 12; at the third, 13; at the fourth, 10; and at the fifth, $13\frac{1}{2}$. Then $11\frac{1}{2} + 12 + 13 + 10 + 13\frac{1}{2} = 60$; and $\frac{60}{5} = 12$ seconds for the mean time that the floats took to pass the 100 ft., $\frac{4}{5}$ this distance $= 80$ ft. for the mean velocity of the stream in 12 seconds; $12 : 60 :: 80 : 400$ ft. for the velocity of the stream per minute; $400 \times 8 \times 2 = 6400$ cub. ft., the required answer.

To abridge calculation, Table 13 shows mean velocities corresponding to surface velocities from 120 to 800 ft. per minute at one glance.

Table 13.—*Surface and Mean Velocities of Water in ft. per minute.*

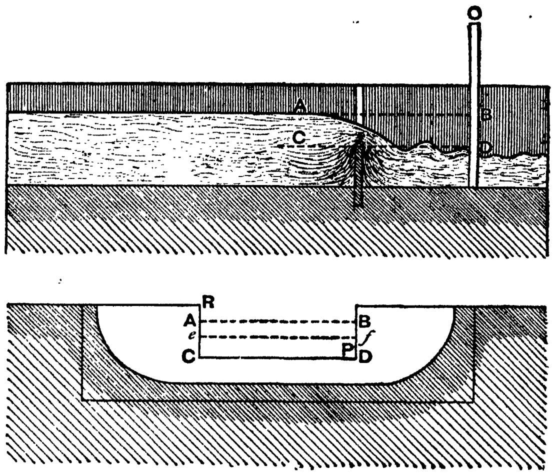
Surface Velocity.	Mean Velocity.	Surface Velocity.	Mean Velocity.	Surface Velocity.	Mean Velocity.
120	98·00	212·5	182·40	310	273·1
122·5	100·25	215	184·75	315	277·8
125	102·50	217·5	187·05	320	282·5
127·5	104·75	220	189·35	325	287·2
130	107·00	222·5	191·65	330	291·9
132·5	109·25	225	193·95	335	296·6
135	111·55	227·5	196·30	340	301·2
137·5	113·80	230	198·60	345	305·9
140	116·05	232·5	200·90	350	310·6
142·5	118·30	235	203·25	355	315·3
145	120·60	237·5	205·55	360	320·1
147·5	122·85	240	207·85	365	324·8
150	125·15	242·5	210·20	370	329·5
152·5	127·40	245	212·50	375	334·2
155	129·65	247·5	214·85	380	338·9
157·5	131·95	250	217·15	385	343·6
160	134·20	252·5	219·50	390	348·3
162·5	136·50	255	221·80	395	353·0
165	138·80	257·5	224·15	400	357·8
167·5	141·05	260	226·45	405	362·5
170	143·35	262·5	228·80	410	367·2
172·5	145·65	265	231·10	415	371·9
175	147·95	267·5	233·45	420	376·7
177·5	150·20	270	235·75	425	381·4
180	152·50	272·5	238·10	430	386·1
182·5	154·80	275	240·45	435	390·8
185	157·10	277·5	242·75	440	395·6
187·5	159·40	280	245·10	445	400·3
190	161·70	282·5	247·45	450	405·1
192·5	164·00	285	249·75	500	452·5
195	166·30	287·5	252·10	550	500·0
197·5	168·60	290	254·45	600	547·7
200	170·90	292·5	256·75	650	595·5
202·5	173·20	295	259·10	700	643·3
205	175·50	297·5	261·45	750	691·2
207·5	177·80	300	263·75	800	739·2
210	180·10	305	268·40		

(*c*) More Correct Method.—Look for some convenient portion of the watercourse, where the water is running slowly. In a perpendicular position and at right angles across it, fix an overfall of boards, as is shown in Figs. 4, 5, in such a manner that the water shall accumulate behind it so high that it will flow over the horizontal edge of the rectangular opening R P, and afterwards have ample room for its free escape. The edges of the boards forming the opening should be sharp and smooth, and all leaks round the bottom and sides carefully closed with clay, in order that the whole water may pass through the opening *e f*. The cross section of the water should be at least 8 times the length of notch *e f*, and the depth of the water under C D should be 4 times

Water—continued.

the depth of B D. At a distance below the overfall a rod O is fixed vertically, having a mark D at the exact level of the edge of the notch C D. When the water has risen to its greatest height, and its surface observed to be horizontal, the depth from the surface of the water A B to the mark on the rod D is noted in inches in column 1 of Table 14. Then on the same line with that number in

Figs. 4, 5.



Overfall for Measuring Stream.

column 3 of Table 14 is a number which, if multiplied by *e f* the width of the notch in inches, will give the quantity of water in cub. ft. per minute, providing the width of the notch is less than 7 times the depth B D, but when the width *e f* is more than 7 times the depth that D is below B, column 2 is taken; when *e f* is equal to B D the quantity of water discharged through the notch will be as much less as the quantity contained in column 3 of Table 14 is to that contained in 2.

Ex. 1.—When *e f* and B D are each 24 in., column 3 in Table 14 gives a discharge of 47·515 cub. ft. of water in one minute, and column 2 gives 50·465. The difference of these two numbers is 2·95. This difference subtracted from 47·515, the remainder will be 44·55 cub. ft. of water discharged per minute by every inch in width of the notch when B D and *e f* are of the dimensions now given.

Table 14.—*Quantity of Water discharged over Weirs or Notches in cub. ft. per minute by every inch of their length.* Column 2 is calculated from Smeaton's experiments; column 3 according to DU BUAT'S.

1. Depth falling over.	2. Discharge per minute over Weir.	3. Discharge per minute over Notch.	1. Depth falling over.	2. Discharge per minute over Weir.	3. Discharge per minute over Notch.
in.	cub. ft.	cub. ft.	in.	cub. ft.	cub. ft.
0·25	·053	·050	10·75	15·128	14·244
0·5	·115	·143	11	15·659	14·743
0·75	·278	·262	11·25	16·196	15 249
1	·429	·404	11·5	16·739	15·760
1·25	·599	·565	11·75	17·296	16·277
1·5	·788	·742	12	17·926	16·799
1·75	·993	·936	12·5	18·969	17·860
2	1·214	1·143	13	20·119	18·942
2·25	1·448	1·364	13·5	21·299	20·055
2·5	1·697	1·597	14	22·484	21·169
2·75	1·957	1·843	14·5	23·699	22·313
3	2·230	2·110	15	24·935	23·477
3·25	2·515	2·368	15·5	26·192	24·661
3·5	2·810	2·646	16	27·470	25·864
3·75	3·117	2·935	16·5	28·768	27·085
4	3·434	3·233	17	30·085	28·326
4·25	3·761	3·541	17·5	31·422	29·585
4·5	4·097	3·858	18	32·778	30·862
4·75	4·443	4·184	18·5	34·153	32·156
5	4·799	4·518	19	35·517	33·469
5·25	5·163	4·861	19·5	36·960	34·799
5·5	5·536	5·213	20	38·390	36·146
5·75	5 918	5·572	20·5	39·839	37·509
6	6·308	5·939	21	41·305	38·890
6·25	6·706	6·314	21·5	42·789	40·287
6·5	7·113	6·697	22	44·291	41·701
6·75	7·527	7·087	22·5	45·809	43·131
7	7·949	7·484	23	47·344	44·576
7·25	8·379	7·889	23·5	48·897	46·038
7·5	8·816	8·300	24	50·465	47·515
7·75	9·260	8·719	25	53 652	50·517
8	9·712	9·144	26	56·903	53·576
8·25	10·171	9·576	27	60·218	56·697
8·5	10·636	10·015	28	63·594	59·875
8·75	11·101	10·460	29	67·050	63·111
9	11·589	10·911	30	70·528	66·404
9·25	12·075	11·369	31	74·083	69·752
9·5	12·568	11·833	32	77·698	73·154
9·75	13·067	12·303	33	81·367	76·602
10	13·573	12·779	34	85·094	80·118
10·25	14·085	13·262	35	88·875	83·678
10·5	14·604	13·750	36	92·711	87·290

When using Table 14 the breadth of notch must not exceed 6 times the depth of the water running over it.

Table 15 is used for common weirs with straight approach, but when the approach is rough, a medium between these quantities is taken.

—Vel… din… Sh… ead…

Head of Water from the Surface to Centre of of Sluice Opening.	Velocity of Water when the Head of Pressure is less than 6 times the Depth of the Sluice Opening.	Velocity of Water when the Head of Pressure is more than 6 times the Depth of Sluice Opening.	Head of Water from the Surface to Centre of Sluice Opening.	Velocity of Water when the Head of Pressure is less than 6 times the Depth of the Sluice Opening.	Velocity of Water when the Head of Pressure is more than 6 times the Depth of Sluice Opening.	Head of Water from the Surface to Centre of Sluice Opening.	Velocity of Water when the Head of Pressure is less than 6 times the Depth of the Sluice Opening.	Velocity of Water when the Head of Pressure is more than 6 times the Depth of Sluice Opening.
ft. in.			ft. in.			ft. in.		
0 4	3·09	2·956	1 2	5·77	5·530	2 10½	9·06	8·681
0 4¼	3·18	3·047	1 2¼	5·88	5·618	3 0	9·25	8·868
0 4½	3·27	3·135	1 3	5·98	5·716	3 1½	9·45	9·051
0 5	3·45	3·305	1 3½	6·07	5·819	3 3	9·55	9·133
0 5½	3·62	3·466	1 4	6·17	5·911	3 4½	9·82	9·305
0 6	3·78	3·621	1 4½	6·27	6·004	3 6	9·99	9·579
0 6½	3·93	3·868	1 5	6·36	6·094	3 7½	10·18	9·749
0 7	4·08	3·910	1 5½	6·45	6·183	3 9	10·35	9·915
0 7½	4·23	4·047	1 6	6·54	6·271	3 10½	10·52	10·079
0 8	4·36	4·181	1 7	6·72	6·443	4 0	10·70	10·209
0 8½	4·50	4·309	1 8	6·90	6·610	4 2	10·91	10·451
0 9	4·63	4·436	1 9	7·07	6·773	4 4	11·13	10·658
0 9½	4·75	4·555	1 10	7·24	6·933	4 6	11·34	10·861
0 10	4·88	4·674	1 11	7·40	7·088	4 8	11·55	11·060
0 10½	5·00	4·789	2 0	7·56	7·241	4 10	11·75	11·256
0 11	5·12	4·902	2 1½	7·80	7·464	5 0	11·95	11·449
0 11½	5·23	5·012	2 3	8·02	7·680	5 3	12·25	11·737
1 0	5·34	5·120	2 4½	8·24	7·891	5 6	12·53	12·007
1 0½	5·45	5·223	2 6	8·45	8·095	5 9	12·82	12·278
1 1	5·56	5·327	2 7½	8·66	8·295	6 0	13·09	12·488
1 1½	5·67	5·431	2 9	8·96	8·491			

Water—continued.

Ex. 2.—Required the quantity of water in cub. ft. per minute discharged through a notch 60 in. long and 9 in. deep from B to D. In that case, as the distance from B to D is less than 7 times the distance from *e* to *f*, we take column 3 to find the quantity. Then opposite, in column 1, the corresponding number is 10·91, and this multiplied by 60, the length, gives 654·6 cub. ft. per minute.

Ex. 3.—Let B D the depth be 12 in., and *e f* the length 100 in., to find the number of cub. ft. that would pass through this opening per minute. In this case column 2 is taken. Opposite 12 in. deep is 17·926, which multiplied by the length, 100 in., will give 1700·926 cub. ft. per minute. Column 2 is in accordance with Smeaton's experiments, which were made on water running in parallel channels, and flowing over the edge of a plank placed horizontally and at right angles across the entire breadth of a weir or stream, offering no lateral obstruction to the water flowing over it. But column 3 was calculated for a waste board, having a notch cut in it narrower than the channel in which it was placed, in consequence of which the water, in meeting the ends of the notch, and afterwards turning into the opening, contracts its passage, and causes a less discharge in a given time: the breadth of the notch and depth of the water being the same in both cases.

If the quantity of water that passes through a sluice opening be required, see the velocity of the water in Table 15 corresponding to the given head of water, which, if multiplied by the area of the sluice opening, will be the number of cub. ft. passing per second.

WATER: *Flumes and Ditches.*

Wet Perimeter.—If a flume or ditch is 20 in. wide, 6 in deep, and full of water, its wet perimeter is $20 + 6 + 6 = 32$ in. If of the same dimensions, but only containing 3 in. of water, the wet perimeter is $20 + 3 + 3 = 26$ in. The same flume again, if empty, has no wet perimeter at all. In other words, the wet perimeter of a water-channel is the length of so much of its base and sides as is wetted by the water.

To find the Area of a Section of a Flume with Straight Sides.—Multiply the width of bottom (in inches) by the height of sides (in inches), the product will be the area in sq. in., which, divided by 144, gives the area in sq. ft. *Ex.*—What is the area of a section of a flume 20 in. wide and 15 in. high? *Ans.*—20 multiplied by $15 = 300$, which divided by $144 = 2{\cdot}08$ sq. ft.

To find the Area of the Section of a Ditch with Sloping Sides.—Add together the width at top and bottom (in inches), multiply this sum by the depth (in inches), and divide the result by 2. The quotient, divided by 144, will be the area in sq. ft. *Ex.*—What is the area of the cross-section of a ditch 60 in. wide at the top, 36 in. at the bottom, and 12 in. deep? *Ans.*—$60 + 36 = 96$, which multiplied

Water—continued.

by 12 = 1152, and this divided by 2 = 576 sq. in., which divided by 144 = 4 sq. ft.

To find the Area of the Cross-section of a Ditch whose Sides slope to a Point at the Bottom.—Multiply the width (in inches) by half the depth (in inches), and divide the product by 144. The result is the area in sq. in. *Ex.*—What is the area of a pointed ditch 60 in. wide and 18 in. deep in the centre? *Ans.*—60 multiplied by 9 (half the depth) = 540 sq. in., which divided by 144 = 3·75 sq. ft. (Von Wagenen.)

Water: *To determine the Capacity of Ditches, Canals, or Flumes.* (Hendy.)

In cases where the sectional areas are equal, but of different forms:

The simplest form of construction of a ditch or canal is that in which the width of the bottom is made equal to one of the sides, and in which the base to the perpendicular of the side slope is as 3 : 4; and this form has been adopted as the standard where the topography of the ground will admit.

The relative carrying capacity for trapezoidal form, base : depth of slope : : 3 : 4; bottom width : depth : : 5 : 4. Coefficiency of capacity = 1000.

Trapezoidal form, base : depth of slope : : 1 : 1; bottom width = depth, ·994.

Flume, 2 : 1, ·961; semi-hexagonal, 1·008; square, 925; semi-circular, 1·056.

The fall being 8 ft. to the mile, and the sectional area of a square flume being 11·52 sq. ft., what will be its carrying capacity per second?

In Table 16, in column headed "fall per mile," find the given fall 8 ft., and opposite in column headed (6′·6–3′–2′·4) or a sectional area of 11·52 sq. ft. will be found 25·60 cub. ft., which, multiplied by the coefficient for a square given above, gives 25·60 × ·925 = 23·68 cub. ft., or × ·50 = 1184 miners' inches.

The tables given to determine the flow of water through ditches, canals, or flumes have been computed upon the assumption that they are generally smooth and straight.

Water: *To determine Proportions of Channels.* (Thiré.)

Where artificial channels or flumes have to be constructed for conveying water for power purposes, there is often considerable uncertainty in determining the relative proportions and dimensions of the area and inclination of the channel, and the quantity and velocity of the water.

Table 16.—WATER: *Flow in Open Channels—Base to Perpendicular of the Side Slopes being as* 3 : 4. (Hendy.)

Fall per Mile.	Fall per Rod.	T 2·2 ft. B 1·0 ft. D 0·8 ft. Section 1·28 sq. ft.	T 3·3 ft. B 1·5 ft. D 1·2 ft. Section 2·88 sq. ft.	T 4·4 ft. B 2·0 ft. D 1·6 ft. Section 5·12 sq. ft.	T 5·5 ft. B 2·5 ft. D 2·0 ft. Section 8·0 sq. ft.	T 6·6 ft. B 3·0 ft. D 2·4 ft. Section 11·52 sq. ft.	T 7·7 ft. B 3·5 ft. D 2·8 ft. Section 15·68 sq. ft.	T 8·8 ft. B 4·0 ft. D 3·2 ft. Section 20·48 sq. ft.
ft.	in.	cub. ft.	cub. ft.	cub ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
1	·0375	0·45	1·33	2·67	5·57	9·05	13·46	20·26
2	·0750	0·63	1·88	3·87	7·88	12·80	19·04	28·64
3	·1125	0·77	2·30	4·74	9·65	15·67	23·32	35·08
4	·1500	0·89	2·65	5·47	11·14	18·52	26·93	40·51
5	·1875	1·00	2·97	6·12	12·46	20·24	30·11	45·30
6	·2250	1·09	3·25	6·70	13·65	22·17	32·98	49·62
7	·2625	1·18	3·42	7·24	14·74	23·94	35·63	53·58
8	·3000	1·26	3·75	7·73	15·75	25·60	38·08	57·28
9	·3375	1·34	3·98	8·21	16·71	27·15	40·39	60·76
10	·3750	1·41	4·19	8·65	17·61	28·62	42·57	64·05
11	·4125	1·48	4·40	9·07	18·47	30·02	44·65	67·18
12	·4500	1·54	4·60	9·48	19·30	31·35	46·64	70·65
13	·4875	1·61	4·78	9·86	20·08	32·63	48·54	73·03
14	·5250	1·67	4·96	10·24	20·84	33·87	50·38	75·79
15	·5625	1·73	5·14	10·60	21·57	35·05	52·14	78·44
16	·6000	1·78	5·31	10·94	22·27	36·20	53·86	81·02
17	·6375	1·84	5·47	11·28	22·96	37·31	55·51	83·51
18	·6750	1·89	5·63	11·60	23·63	38·39	57·11	85·93
19	·7125	1·94	5·78	11·92	24·28	39·44	58·58	88·29
20	·7500	1·99	5·93	12·23	24·91	40·47	60·21	90·58
21	·7875	2·04	6·08	12·54	25·53	41·47	61·70	92·82
22	·8250	2·09	6·22	12·83	26·12	42·45	63·15	95·00
23	·8625	2·14	6·36	13·12	26·71	43·40	64·57	97·15
24	·9000	2·18	6·50	13·40	27·29	44·34	65·95	99·23
25	·9375	2·23	6·63	13·68	27·98	45·24	67·32	101·28

T signifies top width; B, bottom width; D, depth.

Table 16—*continued.*

Fall per Mile.	Fall per Rod.	T 9·9 ft. B 4·5 ft. D 3·6 ft. Section 25·92 sq. ft.	T 11 ft. B 5 ft. D 4 ft. Section 32 sq. ft.	T 13·2 ft. B 6·0 ft. D 4·8 ft. Section 46·09 sq. ft.	T 16·4 ft. B 7·0 ft. D 5·6 ft. Section 62·72 sq. ft.	T 17·6 ft. B 8·0 ft. D 6·4 ft. Section 81·92 sq. ft.	T 19·8 ft. B 9·0 ft. D 7·2 ft. Section 103·68 sq. ft.	T 22 ft. B 10 ft. D 8 ft. Section 128 sq. ft.
	in.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
1	·0375	28·04	37·1	58·4	96·5	138·3	189·2	261·2
2	·0750	39·67	52·4	82·7	136·4	195·7	267·6	369·4
3	·1125	48·59	64·2	101·4	167·1	239·6	327·7	451·3
4	·1500	59·10	74·1	117·1	192·9	276·7	378·4	522·3
5	·1875	62·71	82·9	130·9	215·7	309·3	423·1	584·0
6	·2250	68·70	90·8	143·4	236·3	338·8	463·5	639·8
7	·2625	74·19	98·1	154·8	255·3	366·0	500·5	691·0
8	·3000	79·53	104·8	165·5	272·9	391·2	535·1	738·7
9	·3375	84·14	111·1	175·6	289·4	415·0	567·6	783·5
10	·3750	88·68	117·1	185·1	305·0	437·4	598·2	825·9
11	·4125	93·02	122·9	194·1	319·9	458·7	613·2	866·2
12	·4500	97·15	128·4	202·8	334·2	479·1	655·4	925·6
13	·4875	101·13	133·6	211·1	347·8	498·7	682·1	941·7
14	·5250	104·94	138·7	219·0	360·9	517·5	707·8	977·2
15	·5625	108·63	143·5	226·6	373·6	535·7	732·8	1011·5
16	·6000	112·18	148·2	234·1	385·9	553·3	756·7	1044·7
17	·6375	115·64	152·4	241·3	397·8	570·3	780·1	1076·9
18	·6750	118·99	157·2	248·3	409·3	586·9	802·7	1108·1
19	·7125	122·26	161·5	255·1	420·5	601·5	824·8	1138·4
20	·7500	125·43	165·7	261·7	431·4	618·5	846·1	1168·0
21	·7875	128·53	169·8	268·2	442·0	633·9	867·0	1196·8
22	·8250	131·55	173·8	274·5	452·5	648·8	887·4	1225·0
23	·8625	134·51	177·7	280·7	462·9	663·4	907·4	1252·6
24	·9000	137·40	181·5	286·7	472·6	677·7	926·9	1279·5
25	·9375	140·24	185·3	292·6	482·3	691·6	946·0	1306·0

T signifies top width; B, bottom width; D, depth.

Table 17.—WATER: *Flow in Open Channels—Base to Perpendicular of the Side Slopes being as* 2 : 1. (Hendy.)

Fall per Mile.	Fall per Rod.	T 6 ft. B 2 ft. D 1 ft. Section 4 sq. ft.	T 9 ft. B 3 ft. D 1·5 ft. Section 9 sq. ft.	T 12 ft. B 4 ft. D 2 ft. Section 16 sq. ft.	T 16 ft. B 6 ft. D 2·5 ft. Section 27·5 sq. ft.	T 22 ft. B 10 ft. D 3 ft. Section 48 sq. ft.	T 28 ft. B 12 ft. D 4 ft. Section 80 sq. ft.	T 40 ft. B 20 ft. D 5 ft. Section 150 sq. ft.
ft.	in.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
·5 ..	·01875	1·27	3·85	8·63	18·11	38·79	78·2	188·1
·6667	·0250	1·46	4·44	9·96	20·91	44·79	90·3	217·2
·8333	·03125	1·63	4·96	11·14	23·38	50·08	101·0	242·8
1· ..	·0375	1·79	5·44	12·20	25·61	54·86	110·6	266·0
1·25 ..	·046875	2·00	6·08	13·64	28·68	61·32	123·7	297·4
1·5 ..	·05625	2·19	6·67	14·96	21·34	67·26	135·7	326·1
1·75 ..	·065625	2·37	7·19	16·14	33·88	72·57	146·4	351·8
2· ..	·0750	2·53	7·69	17·26	36·22	77·58	156·5	376·1
2·25 ..	·084375	2·68	8·16	18·30	38·42	82·29	165·9	399·0
2·5 ..	·09375	2·83	8·60	19·29	40·50	86·72	174·9	420·6
3· ..	·1125	3·10	9·42	21·14	44·36	95·00	191·6	460·7
3·5 ..	·13125	3·35	10·17	22·83	47·91	102·60	207·0	497·6
4· ..	·1500	3·58	10·87	24·41	51·22	109·70	221·3	531·9
4·5 ..	·16875	3·79	11·54	25·88	54·33	116·30	234·7	564·2
5· ..	·1875	4·00	12·16	27·29	57·27	122·70	247·4	594·8
6· ..	·2250	4·38	13·31	29·89	62·74	134·40	271·0	651·5
7· ..	·2625	4·73	14·39	32·29	67·73	145·10	292·7	703·6
8· ..	·3000	5·06	15·38	34·52	72·43	155·20	312·9	752·2
9· ..	·3375	5·37	16·31	36·61	76·83	164·60	331·9	797·9
10· ..	·3750	5·66	17·19	38·59	80·99	173·50	349·9	841·1
11· ..	·4125	5·93	18·03	40·47	84·94	181·90	366·9	882·1
12· ..	·4500	6·20	18·74	42·27	88·72	190·10	383·2	921·3

T signifies top width; B, bottom width; D, depth.

Water—continued.

Let H = total height from source of supply to tail-race;
h = effective height of fall at end of channel;
l = length of the channel;
S = cross-section ,,
i = inclination ,,
Q = discharge ,,
v = mean velocity of the current.

Then $H = h + l\,i$ .. .. (1)

and $Q\,h = Q\,(H - l\,i)$ = effective motive force at disposal.

Also $Q = S\,v$ .. .. (2)

and $i = m\,v^2$ .. .. (3)

where m is a coefficient depending on the section of the channel and the nature of its walls or banks.

From (2) and (3) the available work will be found to be:—

$$S\,v\,(H - l\,m\,v^2).$$

Then, v being the variable, the maximum:—

$$H = 3\,l\,m\,v^2;$$

or, from (3),

$$l\,i = \tfrac{1}{3}\,H.$$

Now $l\,i$ is the height lost by the gradient or inclination of the channel. Consequently: of all channels of a given length and section, that which supplies the greatest motive-power at its extremity is the one whose inclination is equal to one-third of the total fall, leaving two-thirds of the height available for motive purposes.

Remarks. (1) The above applies to cases where part only of the water is taken off by the canal. If the whole stream is diverted, the gradient should be limited to that strictly necessary, so as to utilise the greatest possible height of fall.

(2) The gradient must of course be limited by the velocity which the banks of the canal can stand without damage.

(3) In practice, the gradient would not be constant throughout. In parts where the construction is difficult and expensive, a greater fall and smaller cross-section would be adopted, and *vice versâ*; but the above rule, without being mathematically correct, will furnish a useful guide for the mean average gradient.

WATER: *Experiments to test the relative carrying powers of one 20-in. and two 10-in. Flumes.* (Vinton.)

First Experiment—Flume Level.

Area of discharge	0·139 sq. ft.
Velocity	1·985 ft.
Mean depth	0·13 „
Actual discharge	0·276 cub. ft.
Theoretical discharge by formula $Q\ 5 \cdot 6\, a \dfrac{H}{\sqrt{\overline{H \times h}}}$	0·269 „

Second Experiment—Flume Level.

Area of discharge	0·347 sq. ft.
Velocity	2·02 ft.
Mean depth	0·23 „
Actual discharge	0·702 cub. ft.
Theoretical discharge	0·716 „

First Experiment on Graded Flumes; grade ¼ in. to box of 12 ft. = $\frac{1}{576}$ = 0·0017.

Area of discharge	0·295 sq. ft.
Velocity	2·22 ft.
Perimeter	2·02 „
Grade	0·0017 ft.
Actual discharge	0·657 cub. ft.
Theoretical grade by formula sin. $= \dfrac{P}{A}\, V_2\, \dfrac{1}{1000}$	0·0033 ft.
Area of discharge	0·147 sq. ft.
Velocity	1·90 ft.
Perimeter	1·18 „
Grade	0·0017 ft.
Actual discharge	0·279 cub. ft.
Theoretical grade	0·0028 „

Double flume carries 0·177 more than twice the single on this grade.

Second Experiment on Grade; grade ½ in. to 12 ft. = 0·0035.

Area of discharge	0·295 sq. ft.
Velocity	2·271 ft.
Perimeter	2·02 „
Grade	0·0035 ft.
Actual discharge	0·671 cub. ft.
Theoretical grade	0·0035 „

Water—continued.

Area of discharge..	0·147 sq. ft.
Velocity..	2·00 ft.
Perimeter	1·18 ,,
Grade	0·0035 ft.
Actual discharge	0·287 cub. ft.
Theoretical grade..	0·0032 ,,

Discharge of double flume is 0·168 more than two singles on this grade.

Third Experiment on Grade; grade ¾ in. to 12 ft. = 0·0052.

Area of discharge..	0·295 sq. ft.
Velocity..	2·8 ft.
Perimeter	2·02 ,,
Grade	0·0052 ft.
Actual discharge	0·827 cub. ft.
Theoretical grade	0·0053 ,,
Area of discharge..	0·147 sq. ft.
Velocity..	2·21 ft.
Perimeter	1·18 ,,
Grade	0·0052 ,,
Actual discharge	0·325 cub. ft.
Theoretical grade..	0·0035 ,,

Discharge of double flume is 0·272 more than two singles on this grade.

The least wet perimeter that will hold or carry a given volume is attained when the width of bottom is 1¾ to 2¼ times the depth of the sides.—For example, a channel having a cross-section of 510 sq. in. will develop the least amount of friction when its dimensions are 15 by 34, or 17 by 30, or somewhere between these measurements. A knowledge of this fact will be found serviceable in constructing flumes. The least perimeter, of course, requires the least lumber, and many thousand or million feet may be saved in a long flume by building in the correct proportion.

When the head of the flume is above timber line, or in high altitudes where ice forms early in the fall, it is an advantage in many respects to have it so narrow in width that an ice-crust can easily form itself from bank to bank. If this is secured, water will often flow 4–6 weeks longer than otherwise. The reasons are obvious.

The ordinary figures representing loss through evaporation ($\frac{1}{10}$ to $\frac{3}{10}$ in. of surface per day) are much too small for ditches above an altitude of 6000 ft. Evaporation also proceeds much more rapidly

Water—continued.

in shallow water than in deep, and when the velocity is high. Experiments made on a 12-mile wooden flume on the Swan River, Colorado, indicated a loss of 10–18 per cent. daily. This flume is, however, an extreme case, being about 10,000 ft. above sea-level. Probably 1 in. of surface would be an average loss.

Leakage occurs most extensively in gravelly soils; 1–5 in. of surface per day are extreme losses, with an average, perhaps, of about 2 in., which it will be always safe to count on, except in old ditches. A high velocity decreases loss through the soil.

Water channels of uniform section should always have a uniform grade, otherwise there will be an accumulation at some points and a thinning-out at others, with deposits of sand and silt, and increased danger of breakage. It is also highly advantageous in earth ditches to have a complete system of waste-weirs to carry off surplus waters occasioned by floods, and to lessen the damage of breaks. These should be put in just below wherever a new stream falls into the ditch, and just above those places where, by reason of a shelly or crumbly soil, the ditch is weak.

At high altitudes in the spring, difficulty is often encountered in starting the water through heavy accumulations of snow in the ditch, which if long, can be flushed out only with great trouble. This operation will be materially hastened if the ditch is cleaned out in sections of a mile or two each. Cut a hole in the bank a mile from the head, and when the water has soaked that far it will carry off the unmelted snow through this break with great rapidity. As soon as clear, that hole is mended and another is made a mile farther on. (Von Wagenen.)

Cost of Ditching.—When the plough and scraper can be used, ditching can be done at 20 c. (10*d.*) per cub. yd. If the soil is so rocky as to call for the pick and shovel, it will cost 30–40 c. (15–20*d.*) A safe figure to be taken for the construction of a ditch 3 ft. wide at bottom, 4½ ft. wide at top, and 18 in. deep is 15*s.* 3*d.* per rod. It can be done for less. The larger the ditch the less costly it will be in proportion. These figures are based on Californian rates of wages. (Von Wagenen.)

Cost of Ditching. (Kirkpatrick.)

Labour calculated at 6*d.* per hour.

Rock:—

	s.	*d.*	
Excavating	2	0	
Wheeling	0	9	
Dressing	0	9	
Superintendence	0	6	
	4	0	per cub. yd.

Water—continued.

Gravel and Clay:—

	s.	*d.*	
Excavating and wheeling	1	0	
Levelling ditch	0	6	
Making up removed material	0	6	
Superintendence	0	6	
	2	6	per cub. yd.

Total cost, at 4 cub. yd. excavation, per yd. run:—

	s.	*d.*	
Rock, $1\frac{1}{2}$ cub. yd., @ 4*s.*	6	0	
Gravel, $2\frac{1}{2}$ cub. yd. @ 2*s.* 6*d.*	6	3	
	12	3	per yd. run,

or 1078*l.* per mile.

To find what grade per foot must be given to a flume or ditch of uniform section to enable it to discharge a given quantity of water in a given time. Divide the number of cub. ft. of discharge required by the area in sq ft. of the section of the flume. This result is the necessary velocity in ft. per second. Multiply this result by itself. Multiply this product by the wet perimeter in ft., and multiply this product by ·0001114. Divide this product by the area of the section of flume in sq. ft. Call the result A. Multiply the velocity in ft. per second by the wet perimeter in ft., and multiply this product by ·00002426. Divide this product by the area of the section of the flume in sq. ft. Call the quotient B. Add together A and B. The result is the grade per ft. in decimals of a ft. which must be given to the flume to make it carry the required water. *Ex.*—What grade per ft. of length must be given to a 20-in. flume whose sides are 11 in. high, in order that it may deliver 28 cub. ft. of water per second steadily? *Ans.*—Wet perimeter, 42 in. = 3·5 ft. Area of section, 240 sq. in. = 1·66 sq. ft. Discharge = 28 cub. ft. Then, dividing the discharge (28) by the area of section (1·66), we have 16·86 as the velocity in ft. per second. The velocity (16·86) multiplied by itself equals 284·25; multiplying this by wet perimeter (3·5) produces 994·87; multiplying again by ·0001114 produces ·1108; dividing this by area of section (1·66) gives ·0667. Call this A. Multiplying the velocity (16·86) by wet perimeter (3·5), and the product by ·00002426, produces ·0014315, which divided by the area of the section of the flume (1·66) = ·00086. Call this B. Adding A (·0667) to B (·00086), we have as a final result ·06756, which is the grade per ft. in decimals of a ft. If we multiply this result (·06756) by 1000, we have the grade per 1000 ft., which will be 67·5 ft. To reduce this result to the ordinary terms—viz. in. per box of 12 ft. —divide first 1000 by 12, which produces 83·33 (which of course

Water—continued.
represents the number of 12-ft. boxes in a 1000-ft. flume). Then, the grade being 67·5 ft. in 83·33 boxes, for each box, it would be the result of dividing 67·5 by 83·33, which is ·79, or the grade would be ·79 ft. per box of 12 ft. Finally, there being 12 in. in a ft., we multiply ·79 by 12 and obtain 9·48 in. per box, or nearly 9½ in. (Von Wagenen.)

To find the average velocity and discharge secured in a flume or ditch of uniform cross-section and grade. Multiply area of cross-section in sq. ft. by the grade in ft. per ft., and the product by 9000. Divide this result by the wet perimeter in ft. Extract the square root of the quotient. From the result subtract ·1089. The result equals the mean velocity of the water in ft. per second. Multiply the area of cross-section by the mean velocity. The result equals the discharge in cub. ft. per second. *Ex.*—What is the discharge attained in a 30-in. flume with 12-in. sides, having a uniform grade of $\frac{1}{100}$ (·01 ft. for every ft. of length)? *Ans.*—Multiplying the area of cross-section (2·5 sq. ft.) by the grade (·01) produces ·025; multiplying this by 9000 yields 225; dividing this by the wet perimeter (4·5) gives 50, whose square root is 7·0711; subtracting from this the decimal ·1089, we have 6·9622, which is the mean velocity in ft. per second. This is accurate only for a flume. In a ditch, where friction is greater, it will be necessary to subtract about 10 per cent. (or ·6962) from the result found, leaving 6·266 as the corrrect figure. Then multiply the mean velocity (6·9622) by the area of cross-section (2·5); we have 17·40, which is the discharge in cub. ft. per second. (Von Wagenen.)

To find the section of a ditch or flume of uniform grade which will discharge a given quantity of water in a given time. There is no simple rule that will solve this problem, and an answer must be sought experimentally upon the following plan:—Assume a convenient section, and, the grade being known, calculate its discharge. If this discharge is greater or less than the required one, try again with a smaller or larger section until the correct one is found. (Von Wagenen.)

Cost.—With lumber at 12 to 15 dols. per 1000, delivered at the head of the flume, so that it can be floated down, a flume 2½ ft. wide and 2½ ft. high can be finished at a cost of 3·85 dols. (16*s.*) per box (of 12 ft in length): and one 6 ft. wide and 3½ ft. high at 8½ dols. (35*s.* 6*d.*) per box, at Californian rates. (Von Wagenen.)

WATER: *Piping.*

To find the velocity attained in a cylindrical iron pipe, laid straight or with easy curves, its head, length, and diameter being known. Multiply the diameter in ft. by the head in ft. Call this product A. Add together the total length of pipe in ft., and 54 times its diameter in ft. Call this sum B. Divide A by B. Extract the square root of the quotient; multiply this root by 48. The product will be the velocity in ft. per second. *Ex.*—What velocity

Water—continued.

will be attained in a pipe 12,600 ft. long, 6 in. (·5 ft.) in diameter, and having a head of 200 ft.? *Ans.*—Multiply diameter (·5) by head (200) = 100. Call this product A. Add to the total length (12,600 ft.) 54 times its diameter: ·5 multiplied by 54 equals 27 = 12,627. Call this sum B. Divide A (100) by B (12,627) = ·0079. Extract the square root of this result, which = ·0889. Multiply this root by 48 = 4·26, which is the velocity per second in ft. (Von Wagenen.)

To find how many cub. ft. of water per second will be discharged from a cylindrical iron pipe, straight or with easy curves, its head, length, and diameter being known. Ascertain the velocity by preceding rule. Then multiply the velocity thus attained by the area in sq. ft. of a section of the pipe. The result will be the discharge per second in cub. ft. (Von Wagenen.)

To find what head of water is necessary for a cylindrical iron pipe, straight or with easy curves, its diameter and length being known, to produce a given discharge per second. Multiply the required discharge in cub. ft. by itself. Call this A. To the total length of pipe add 54 times its diameter. Call this B. Multiply A by B. Call the product C. Divide the diameter in ft. by ·235. Multiply this product by itself continuously four times. Divide C by this product. The quotient will be the head in ft. *Ex.*—What head is necessary to produce a discharge of 12 cub. ft. per second at the end of a pipe 8 in. (·666 ft.) diameter and 350 ft. long, the pipe being straight or with easy curves? *Ans.*—Multiply the discharge (12) by itself = 144; call this A. To the total length (350) add 54 times its diameter (36) = 386; call this B. Multiply A (144) by B (386) = 55,584 (C). Divide the diameter (·666) by ·235 = 2·834. Multiply this product (2·834) by itself continuously four times = 182·801. Divide C (55,584) by this product (182·801) = 304 ft. nearly, which is the required head. (Von Wagenen.)

To find diameter of pipe necessary to carry a given quantity of water per second, its length and total head being known. Multiply the head in ft. by 5280, and divide the product by the length in ft. Call this A. Multiply the discharge in cub. ft. per second by itself, and multiply this product by 5280. Call this B. Divide B by A. Extract the fifth root of the result. Multiply this by ·235. The product is the diameter in ft. *Ex.*—What must be the diameter of a pipe 6000 ft. long, with a head of 400 ft., which will discharge 6 cub. ft. of water per second? *Ans.*—Multiply the head (400) by 5280 = 2,112,000, and divide this product by the length (6000) = 352 (A). Multiply the discharge (6) by itself = 36, and multiply this product by 5280 = 190,080 (B). Divide B (190,080) by A (352) = 540. Extract fifth root of this quotient (540) = 3·52. Multiply this root (3·52) by ·235 = ·8272, which is the required diameter in decimals of a ft. (Von Wageuen.)

To find loss of head by friction in pipes, refer to Table 18, which is calculated for pipes 100 ft. long. Column *a* shows velocity of flow

Water—continued.

in ft. per second; *b*, discharge in cub. ft. per minute; *c*, cub. ft. loss by friction. The bold figures at top of column indicate inside diameter of pipes in inches.

Table 18.—*Loss of Head by Friction.*

a	**3**		**4**		**5**		**6**		**7**		**8**	
	b	*c*	*b*	*c*	*b*	*c*	*b*	*c*	*b*	*c*	*b*	*c*
1	2·95	·196	5·22	·147	8·17	·118	11·77	·098	16·03	·084	20·88	·074
2	5·89	·659	10·44	·494	16·34	·395	23·54	·329	32·05	·282	41·76	·247
3	8·83	1·35	15·67	1·02	24·51	·815	35·32	·679	48·08	·581	62·64	·509
4	11·80	2·28	20·89	1·71	32·69	1·37	47·09	1·14	64·11	·977	83·52	·856
5	14·70	3·43	26·12	2·57	40·87	2·05	58·87	1·71	80·15	1·47	104·40	1·28
6	17·70	4·78	31·34	3·59	49·05	2·87	70·64	2·39	96·18	2·05	125·28	1·79
7	20·60	6·35	36·57	4·77	57·22	3·81	82·41	3·18	112·21	2·73	146·16	2·39
8	23·56	8·14	41·79	6·11	65·40	4·89	94·19	4·07	128·24	3·49	167·04	3·06
9	26·51	10·12	47·02	7·59	73·57	6·07	105·97	5·06	144·27	4·34	187·92	3·79
10	29·45	12·32	52·24	9·24	81·75	7·39	117·74	6·16	160·30	5·28	208·80	4·62
11	32·40	14·71	57·47	11·03	89·92	8·82	129·52	7·36	176·34	6·31	229·68	5·52
12	35·34	17·31	62·70	12·98	98·10	10·38	141·30	8·65	192·37	7·41	250·56	6·49
13	38·33	20·10	67·92	15·08	106·27	12·06	153·07	10·05	208·40	8·61	271·44	7·54
14	41·23	23·12	73·15	17·34	114·45	13·87	164·85	11·56	224·43	9·91	292·32	8·67
15	44·20	26·32	78·38	19·74	122·62	15·79	176·63	13·16	240·46	11·28	313·20	9·87
16	47·12	29·72	83·60	22·29	130·80	17·83	188·40	14·86	256·48	12·74	334·08	11·15
17	50·05	33·33	88·83	25·00	138·97	20·00	200·18	16·67	272·51	14·29	354·96	12·50
18	53·00	37·14	94·05	27·86	147·15	22·29	211·96	18·57	288·54	15·92	375·84	13·93
19	55·95	41·12	99·28	30·84	155·32	24·67	223·73	20·56	304·57	17·62	396·72	15·42
20	58·89	45·32	104·50	33·99	163·50	27·19	235·51	22·66	320·60	19·42	417·60	17·00

a	**9**		**10**		**11**		**12**		**13**		**14**	
	b	*c*	*b*	*c*	*b*	*c*	*b*	*c*	*b*	*c*	*b*	*c*
1	26·47	·065	32·70	·059	39·55	·054	47·10	·049	55·30	·045	64·08	·042
2	52·94	·220	65·40	·198	79·10	·180	94·20	·164	110·60	·152	128·16	·141
3	79·41	·450	98·15	·407	118·65	·370	141·30	·339	165·90	·313	192·24	·291
4	105·90	·760	130·85	·685	158·20	·623	188·40	·570	221·20	·527	256·32	·489
5	132·37	1·14	163·50	1·03	197·76	·932	235·40	·855	276·50	·789	320·40	·735
6	158·84	1·59	196·20	1·43	237·30	1·30	282·50	1·20	331·80	1·10	384·48	1·03
7	185·31	2·12	228·90	1·90	276·85	1·73	329·60	1·59	387·10	1·46	448·57	1·36
8	211·80	2·71	261·60	2·45	316·40	2·23	376·70	2·04	442·40	1·88	512·66	1·75
9	238·29	3·37	294·29	3·03	355·95	2·76	423·80	2·53	497·70	2·33	576·75	2·17
10	264·77	4·11	327·00	3·70	395·50	3·36	470·90	3·08	553·00	2·85	640·84	2·64
11	291·26	4·90	359·70	4·41	435·05	4·01	518·00	3·68	608·30	3·39	704·93	3·15
12	317·74	5·77	392·39	5·19	474·62	4·72	565·10	4·32	663·60	3·99	769·02	3·71
13	344·22	6·70	425·09	6·03	514·17	5·48	612·20	5·03	718·90	4·64	833·10	4·30
14	370·70	7·71	457·79	6·93	553·72	6·30	659·30	5·78	774·20	5·33	897·18	4·95
15	397·18	8·77	490·49	7·90	593·27	7·18	706·35	6·58	829·50	6·08	961·27	5·64
16	423·65	9·91	523·18	8·92	632·82	8·11	753·45	7·43	884·75	6·86	1025·36	6·37
17	450·13	11·11	555·88	10·00	672·37	9·09	800·50	8·33	940·00	7·69	1089·45	7·15
18	476·61	12·38	588·58	11·14	711·92	10·13	847·60	9·29	995·30	8·57	1153·59	7·96
19	503·08	13·71	621·28	12·34	751·52	11·22	894·70	10·28	1050·60	9·49	1217·63	8·81
20	529·56	15·11	653·98	13·60	791·07	12·36	941·75	11·33	1105·90	10·46	1281·72	9·71

Table 18.—*continued.*

a	15		16		17		18		19		20	
	b	*c*	*b*	*c*	*b*	*c*	*b*	*c*	*b*	*c*	*b*	*c*
1	73·58	·039	83·68	·037	94·56	·035	106·00	·033	118·09	·031	130·87	·029
2	147·16	·132	167·36	·123	189·12	·116	212·00	·110	236·18	·104	261·74	·099
3	220·74	·272	251·04	·255	283·68	·239	318·00	·225	354·27	·214	392·61	·204
4	294·32	·457	334·72	·428	378·24	·403	424·00	·380	472·36	·361	523·48	·343
5	367·90	·683	418·40	·640	472·80	·601	530·00	·570	590·45	·537	654·35	·515
6	441·48	·957	502·08	·895	567·36	·841	636·00	·795	708·54	·753	785·22	·715
7	515·07	1·27	585·76	1·19	661·92	1·12	742·00	1·06	826·63	1·00	916·09	·950
8	588·66	1·63	669·45	1·53	756·48	1·44	848·00	1·36	944·72	1·29	1046·96	1·23
9	662·25	2·02	753·14	1·89	851·04	1·78	954·00	1·68	1062·81	1·59	1177·83	1·51
10	735·84	2·46	836·83	2·31	945·60	2·18	1060·00	2·06	1180·90	1·95	1308·70	1·85
11	809·43	2·94	920·52	2·76	1040·16	2·59	1166·00	2·45	1298·99	2·32	1439·57	2·21
12	883 02	3·46	1004·21	3·24	1134·72	3·05	1272·00	2·89	1417·08	2·73	1570·44	2·59
13	986·60	4·02	1087·90	3·77	1229·28	3·55	1378·00	3·35	1535·17	3·17	1701·31	3·02
14	1030·18	4·62	1171·59	4·33	1323·84	4·08	1484·00	3·86	1653 26	3·65	1832·18	3·47
15	1103·77	5·26	1255·28	4·93	1480·40	4·65	1590·00	4·38	1771·35	4·16	1963·05	3·95
16	1177·36	5·94	1338·96	5·58	1512·96	5·25	1696·00	4·96	1889·44	4·69	2093·92	4·46
17	1250·95	6·67	1422·64	6·25	1607·52	5·88	1802·00	5·55	2007·53	5·26	2224·79	5·00
18	1324·54	7·43	1506·32	6·97	1702·08	6·55	1908·00	6·19	2125·62	5·86	2355·66	5 57
19	1398·13	8·22	1590·00	7·71	1796·64	7·26	2014·00	6·86	2243·71	6·49	2486·53	6·17
20	1471·72	9·06	1673·68	8·50	1891·20	8·00	2120·00	7·56	2361·80	7·16	2617·40	6·80

a	22		24		26		28		30	
	b	*c*	*b*	*c*	*b*	*c*	*b*	*c*	*b*	*c*
1	158·36	·027	188·44	·025	221·13	·023	256·56	·021	294·44	·019
2	316·72	·090	376·88	·082	442·26	·076	513·12	·071	588·88	·066
3	475·08	·185	565·32	·169	663·39	·157	769·68	·145	883·32	·136
4	633·44	·312	753·76	·285	884·52	·263	1026·24	·245	1177·76	·228
5	791·80	·466	942·20	·428	1105·65	·394	1282·80	·368	1472·20	·342
6	950·16	·650	1130·64	·600	1326·78	·550	1539·36	·515	1766·64	·478
7	1108·52	·865	1319·08	·795	1547·91	·730	1795·92	·680	2061·08	·635
8	1266·88	1·12	1507 52	1·02	1769·04	·940	2052·48	·875	2355·52	·815
9	1425·24	1·38	1695·96	1·27	1990·17	1·17	2309·04	1·08	2649·96	1·01
10	1583·60	1·68	1884·40	1·54	2211·30	1·42	2565·60	1·32	2941·40	1·23
11	1741·96	2·01	2072·84	1·84	2432·43	1·69	2822·16	1·57	3238·84	1·47
12	1900·32	2·36	2261·28	2·16	2653·56	2·00	3078 72	1·86	3533·28	1·73
13	2058·68	2·74	2449·72	2·52	2874·69	2·32	3335·28	2·15	3827·72	2·01
14	2217·04	3·15	2638·16	2 89	3095 82	2·67	3591·84	2·48	4122·16	2·31
15	2375·40	3·59	2826·60	3·29	3316·95	3·04	3848·40	2·82	4416·60	2·63
16	2533 76	4·06	3015·04	3·72	3538·08	3·43	4104·96	3·19	4711·04	2·97
17	2692·12	4·55	3203·48	4·17	3759·21	3·85	4361·52	3·58	5005·48	3·33
18	2850·48	5·07	3391·92	4·65	3980·34	4·29	4618·08	3·98	5299·92	3·72
19	3008·84	5·61	3580·36	5·14	4201·47	4·75	4874·64	4·41	5594·36	4·11
20	3167·20	6·18	3768·80	5·67	4422·60	5·23	5131·20	4·86	5888·80	4·53

Water: *Flow in Siphons.* (Vodicka.)

In spite of many observations, the nature of the resistance attending the motion of water in pipes is still far from clear. It is

Water—continued.
known that the resistance increases with the length of the pipe and with the diminution of the diameter, and the formula of Weisbach (1) is generally used for determining the velocity of outflow.

$$v = \sqrt{\frac{2 g h}{1 + \eta_0 + \eta \frac{l}{d}}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and

$$h_2 = \eta \frac{v^2}{2 g} \cdot \frac{l}{d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

represents the loss of head due to the frictional resistance. A series of experiments upon a large siphon belonging to the waterworks of Romeno, in Nonsthal, show that the resistance is influenced not only by the velocity of flow, the diameter and length of the pipe, but also to a great extent by the hydraulic pressure on the sides of the pipe. It is a physical fact that the resistance in a pipe full of flowing water does not arise from friction against the pipe itself, but against a thin layer of water which adheres to it. The thickness of these layers, which are quite still or move very slowly, depends on the pressure upon the sides of the pipe. The greater this is, the thicker will be the layer, and therefore the smaller will be the diameter of the free area for flowing. In pipes with a constant or slightly varying fall, the line of hydraulic pressure is about parallel with the pipe. In such a case the pressure is almost the same in every part, and the resistance may be taken as proportional to the length. It is different in the case of a siphon, when the hydraulic pressure varies very much.

At the Romeno waterworks the supply is collected from some springs and from the Ruffré stream into a tank, whence it goes into a masonry and concrete conduit by many curves along the faces of the hills and cliffs, for a distance of about 15 furlongs, to Cavareno, where is a second tank. From this it passes by means of a siphon 938·8 yd. long across the Moscabia valley into a third tank, whence it flows on to Romeno along a second conduit about 15 furlongs in length.

The siphon consists of cast-iron socket pipes, 5 in. internal diam., and has an outlet at the lowest point. In the experiments the water was collected at its outflow in gauged reservoirs, and more water was always brought to the upper end of the siphon than it could take. Three sets of experiments were made, I., II., III., by admitting the water at three points in the siphon on one side of the valley, and letting it off at three points on the other side. In I., where the head was 4·233 m. (13·89 ft.), and the length 553 m. (1814 ft.), the mean of three experiments gave a flow of 8·867 litres

Water—continued.

per second (117·2 gal. per minute), equivalent to a velocity of 0·651 m. (2·136 ft.) per second, whereas the Weisbach formula gives a velocity of 0·895 m. per second.

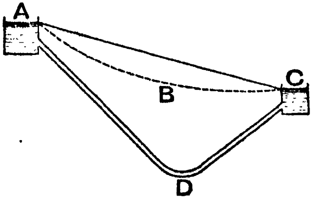
In II. the head was 7·1 m. (23·29 ft.), and the length 517·2 m. (1697 ft.). The mean of five experiments (varying from 8·526 to 8·645) was 8·567 litres per second, equivalent to a velocity of 0·63 m. per second, whereas the formula gives a velocity of 1·227 m. per second.

In III. the head was 19·935 m. (65·405 ft.), and the length 858·4 m. (2816 ft.). The experiments each gave a flow of 20·25 litres per second, equivalent to a velocity of 1·487 m. per second, whereas the formula gives 1·645.

In such experiments it is important that the gauging should not be commenced until the water has been flowing for some time, or until the bubbles caused by the compression of the air, when the water first flows into the bottom of the bend of the siphon, have ceased to rise. For instance, in the third experiment it was almost ½ hour before the bubbles ceased, and a measurement made at first gave only 13·5 litres per second, as compared with the later flow of 18·55 litres.

In every case the outflow of water varies considerably from the amount given by the formula, especially in II., where the head is greater and the sum of the hydraulic side-pressures smaller than in I., and yet the outflow is less. This may be explained as follows:—By the increased head in II. (in comparison with I.) the velocity would be increased, thus the hydraulic pressure would be somewhat lessened, as also would the thickness of the layers of water adhering to the wall of the pipe. The loss of head from friction would, however, be greater, being proportional of the square of this increased velocity. In this way almost the whole of the excess of head in II. over I. is used up. It is clear that the water cannot flow out with less velocity in II. than in I.; therefore, since less water has flowed out, the area of the outflow must have been less, which agrees with the fact that the outflow lies lower than in I., and there is therefore a greater wall-pressure. This indicates that the diminution of the cross-section occurs through increased wall-pressure by the formation of layers of still or almost still water on the wall of the pipe.

Fig. 6.



Loss of Head in Pipes.

In III., with a head of 21 m., the flow of water is greatly increased, and agrees fairly with that arrived at by using the formula, the increased head having overcome the resistance met with.

Water—continued.

From what goes before it follows that the loss of head in pipes is some function of the sum of all the hydraulic side pressures, that is a function of the area A B C D (Fig. 6) or approximately of the area A C D, included between the pipe and the straight line joining its ends.

Substituting in formula (2) F for l,

$$h_2 = \eta \cdot \frac{F}{d} \cdot \frac{v^2}{2g} \quad \cdots \quad (3)$$

Where d is the diameter of pipe, v is the velocity of outflow, and F the area A C D in sq. m.; and from (1) substituting F for l,

$$h = (1 + \eta_0)\frac{v^2}{2g} + \eta\,\frac{F}{d} \cdot \frac{v^2}{2g} \quad \cdots \quad (4)$$

The influence of bends is left out of consideration. Applying this formula to the data obtained from experiments I., II., III., and a fourth made subsequently with a head of 16 m., the value of the coefficient η is determined in each case, and a curve constructed showing the varying values of η as h increases, which gives the following results :—

$h =$	1	2	3	4	5	6	7	8	9	10
$\eta = 0{\cdot}00$	05	11	20	34	58	74	79	80	77	70
$h =$	11	12	13	14	15	16	17	18	19	20
$\eta = 0{\cdot}00$	61	51	41	33	26	20	16	135	12	115

Hydraulic Grade-line.—This is an imaginary straight line, extending from a point on the side of the reservoir denominated the velocity-head, to the outlet of the pipe. If the pipe be constructed exactly on this line, the water flowing through it, no matter what its velocity or volume, will exert no bursting pressure. In other words, the grade of the hydraulic grade-line is such that the velocity caused by the grade is exactly sufficient to carry down all that the pipe will hold, and there is no outward pressure exerted except that on the bottom of the pipe due to the water's weight. If, however, there be a change in the diameter of the pipe at any point, this equilibrium ceases to exist. It is never possible in practice to adopt this line as a course, but generally close approximations can be made to it, and it is highly advantageous to do this wherever possible.

Water—continued.

To find the Hydraulic Grade-line.—Calculate the velocity in pipe due to the total head. Find the head corresponding to this velocity. Lay off this head on the side of the reservoir from the top of the pipe-opening. Its termination will mark the line of the velocity-head. From this point sight to the outlet of the pipe; the line of sight is the hydraulic grade-line.

In constructing a line of piping three cases may arise by reason of the inequalities of the ground to be passed over: (*a*) The pipe may lie below the hydraulic grade-line; (*b*) above it; (*c*) both above and below.

Pipe below Hydraulic Grade-line.— Here is a bursting pressure, varying in power according to its distance below the line. To find this pressure at any point, ascertain the distance of that point vertically below the hydraulic grade-line. Call this measurement the bursting-head—say 6 ft. The pressure, then, on each sq. in. of pipe at that point is equal to the weight of a column of water whose base measures 1 sq. in. and whose height is 6 ft. Thus, 1 sq. in. multiplied by 6 ft. (72 in.) = 72 cub. in. = ·04166 cub. ft. multiplied by 62·5 (wt. of cub. ft. of water) = 2 6 lb., which is the pressure per sq. in. Consequently, if the pipe lies considerably below the hydraulic grade-line, it will need to be of thicker iron than the rest. This law applies in crossing deep hollows.

Pipe above the Hydraulic Line.—Here is a decided loss of head, and consequently of power, in portions of the pipe, if it be the same diameter throughout. Find now that point in the pipe which is highest above the hydraulic grade-line, and from that point draw two new grade-lines, one to the pressure-box and one to the outlet. Along the former calculate the bursting pressure as above, measuring the different heads from the new line. Along the latter there will be no bursting pressure, for the grade of the outlet end of the pipe will be so much greater than that of the reservoir end that it will carry off the water very much faster, and will, in fact, act like a gutter, and be partially empty. The remedy for this is to put in pipes having a decreased diameter. To calculate the requisite diameter, assume that the pipe ended at that point where it is highest above the hydraulic grade-line. Calculate the discharge in cub. ft. at that point. This will give the amount of water in cub. ft. per second which the outlet section must carry. The head will be the vertical distance from the highest to the lowest point.

Pipe both above and below the Hydraulic Grade-line.—The problem now becomes more complicated. Divide the pipe into sections for every passage it makes above the hydraulic grade-line, and make the divisions at the several points where the pipe attains its highest position. Calculate the discharge at the end of each section The first section will have a head equal to the vertical distance between its discharge and the water-level in the pressure-box. All succeed-

Water—continued.

ing heads will be measured from the level of the discharge just below them to their own discharge. These measurements will furnish a series of heads and grades from which the diameters of pipe necessary may be calculated.

Table 19.—WATER: *Strength of Sheet-iron Piping.* (Von Wagenen.)

This table gives the thickness, in inches and decimals of an inch, which iron piping must have to stand a given pressure.

Head of Water, in ft.

Diameter of Pipe, in inches.	100	150	200	250	300	400	500	600	800	1000
	Resulting Pressure against Sides of Pipe, in lb. per sq. in.									
	43·4	65·1	87	109	130	174	217	260	347	434
	Required Thickness of Pipe, in inches or decimals of an inch.									
2	·009	·013	·018	·022	·027	·036	·045	·055	·075	·095
3	·013	·020	·026	·033	·040	·054	·068	·082	·112	·143
4	·017	·026	·035	·045	·053	·072	·090	·110	·149	·191
5	·022	·033	·044	·056	·067	·090	·113	·137	·186	·237
6	·026	·040	·053	·067	·080	·108	·136	·165	·224	·287
7	·030	·046	·062	·078	·093	·126	·159	·193	·261	·333
8	·034	·053	·071	·089	·107	·144	·181	·220	·298	·382
9	·039	·059	·079	·101	·120	·163	·205	·247	·335	·427
10	·044	·066	·089	·112	·134	·181	·227	·275	·373	·475
12	·053	·080	·106	·134	·161	·217	·273	·330	·448	·575
14	·061	·093	·124	·156	·187	·253	·318	·387	·523	·666
16	·069	·106	·142	·178	·214	·288	·363	·440	·596	·763
18	·078	·120	·159	·201	·242	·326	·409	·495	·670	·850
20	·088	·132	·177	·223	·267	·361	·454	·549	·746	·950
24	·105	·159	·213	·268	·321	·433	·545	·660	·895	1·150
30	·132	·198	·267	·336	·402	·543	·681	·825	1·120	1·420
36	·156	·238	·318	·402	·483	·651	·819	·990	1·340	1·710
42	·184	·279	·372	·469	·562	·759	·955	1·160	1·570	2·000
48	·210	·317	·425	·535	·641	·866	1·090	1·320	1·790	2·290

To find what thickness of iron should be used to make a 20-in. pipe which must bear 200 ft. head of water.—The figure given in the table is ·177 in., which, by the following table, corresponds to between No. 5 and No. 6 iron. Or, the head being 100 ft. and the pipe 10 in. diameter, the thickness will be ·044 in., which corresponds nearly to No. 22. In selecting the iron it will always be safer to take the size one larger than that called for by the figures.

TABLE 20.—WATER: *Thickness of the different sizes of sheet-iron from No. 4 up to No. 30.*

No.	4 has a thickness of	·250	in.	No.	18 has a thickness of	·055	in.
,,	5 ,,	·200	,,	,,	19 ,,	·052	,,
,,	6 ,,	·166	,,	,,	20 ,,	·050	,,
,,	7 ,,	·142	,,	,,	21 ,,	·047	,,
,,	8 ,,	·133	,,	,,	22 ,,	·045	,,
,,	9 ,,	·111	,,	,,	23 ,,	·044	,,
,,	10 ,,	·100	,,	,,	24 ,,	·041	,,
,,	11 ,,	·090	,,	,,	25 ,,	·040	,,
,,	12 ,,	·083	,,	,,	26 ,,	·038	,,
,,	13 ,,	·076	,,	,,	27 ,,	·037	,,
,,	14 ,,	·071	,,	,,	28 ,,	·035	,,
,,	15 ,,	·066	,,	,,	29 ,,	·034	,,
,,	16 ,,	·062	,,	,,	30 ,,	·033	,,
,,	17 ,,	·058	,,				

In practice the depression of the pipe leading from the water-box to the pit is rarely more than 5-20 ft. below the hydraulic grade-line; the iron is thus compelled to resist a pressure never over 10 lb. to the sq. in., which ordinary stove-pipe iron will generally do. (Von Wagenen.)

WATER: *Ordinary Dimensions of Iron Feed Pipes.*

Diameter of Pipe.	Pressure.	No. of Iron.	Thickness of Iron.
in.	ft.		in.
22	150	16	0·060
22	150 to 250	14	0·078
22	250 to 310	12	0·098
30	150	14	0·078
30	150 to 275	12	0·098
40	160	..	0·236

The iron used varies generally from No. 16 to No. 11, according to the pressure, the best iron only being employed. The size of the pipe will depend upon the supply of water; with 1500-2000 in. of water, a 22-in. pipe will suffice; where the supply is 3000 in., a 30-in. pipe must be used, and so on.

No. 14 iron will resist a pressure of 300 ft. head, or 130 lb. to the sq. in., and an 11-in. pipe of No. 16 iron, a pressure of 500 ft. or 217 lb. to the in. No. 14 iron is 0·083 in. thick, and weighs 3·35 lb. to the sq. ft.; No. 16 is 0·065 in. thick and 2·63 lb. to the ft. Persons having no practical experience generally make their pipes unnecessarily heavy. (Rep. State Mineralogist, California.)

WATER: *Dams and Reservoirs.*

Following are useful rules by Von Wagenen:—

1. *Water at Rest transmits Pressure equally in all Directions.*—If a pressure of 100 lb. is exerted on the entire surface of the water in a reservoir whose section is 10 sq. ft., this pressure is transmitted in its entirety not only to the base, but to every 10 sq. ft. of its sides. Thus, if the interior surface of the reservoir (base and sides) measures 250 sq. ft., and a pressure of 100 lb. is placed on the water-surface (of 10 sq. ft.), the base and walls will receive a total pressure of 2500 lb. Or if the box be so closed at the top as to leave but 1 sq. ft. of water exposed, and if a pressure of 100 lb. be applied on this 1 sq. ft., an equal pressure will be transmitted to every sq. ft. of interior surface, and the total will consequently be 25,000 lb. Or, to illustrate this remarkable property still more thoroughly, suppose the top of the vessel to be covered with the exception of 1 sq. in. If on this a pressure of 100 lb. is placed, every sq. in. of interior surface will be pressed outward with this weight, which, for the size box under consideration, would amount altogether to 1800 tons.

2. *The Pressure exerted by Water on the Horizontal Bottom of a Vessel* is wholly independent of the shape of the vessel, and is equal to the weight of a column of water whose base is the area of the horizontal bottom, and whose height is equal to the depth of the liquid.

3. *The Pressure of Water on the sides of a Vessel* is equal to the weight of a column of water whose base is equal to the area of the side, and whose height is equal to one-half the depth of the liquid. Owing to this law, the pressure on the walls and base of a cubical vessel is equal to three times the weight of the water contained.

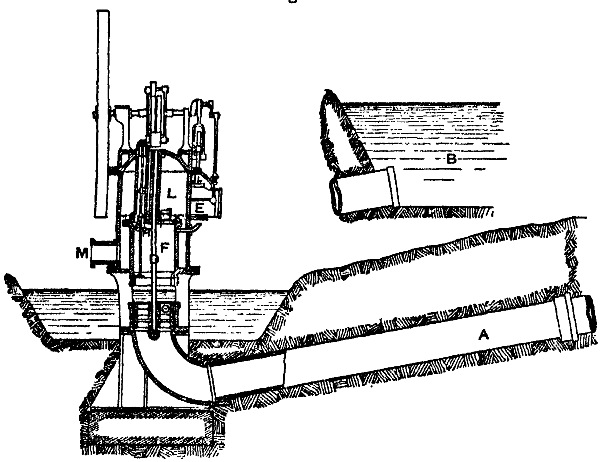
Referring to the third principle just enunciated, it will be seen that the pressure on any surface under water depends upon two things—the depth of water and the area of the surface pressed. For example, what will be the pressure against the inner slope of a dam 50 ft. long, 12 ft. wide, and 12 ft. deep at the *bottom*? *Ans.*—Multiply the area of the slope ($50 \times 12 = 600$) by the average vertical depth in ft. of the centre of gravity of the slope $(6) = 3600$, and multiply this by $62 \cdot 5$ (the weight of 1 cub. ft. of water) $= 225{,}000$ lb.

It will be noted that the pressure is no greater if the water reaches back from the face of the dam for miles, than if it were a reservoir only a few ft. broad. Hence, if a reservoir is built simply for storage, make it large and shallow rather than small of area and deep. The loss by solar evaporation will, it is true, be much greater, but this disadvantage will be counterbalanced, first, by the small leakage; second, by the cheapness of the dam; and, third, by the great safety of the construction.

Pearsall's hydraulic engine (Fig. 7) utilises water power for pumping without the intervention of pumps. The flow pipe A

Water—continued.
conducts water from the source B to the engine, the water flowing freely through main valve C when open as shown. Rod D moves C up and down at proper intervals by means of motor E. At the period of the engine stroke shown, the chamber F contains only air and communicates freely with the atmosphere by pipe G fitted with float valve J. When C is raised and closed it shuts off the flow of water, but does not check it till *completely* closed, because, until chamber F is filled with water up to float H, valve J remains

Fig. 7.



Pearsall's Hydraulic Engine.

open, giving free communication between chamber F and the atmosphere ; consequently the air freely escapes from the chamber and the water freely rises in the chamber. This action takes place *during the closing* of main valve C, consequently no power is wasted in forcing water through the narrowing orifice of this valve, and there is no need to close this valve with great rapidity, and in fact it comes to rest without any concussion. When the water touches float H, it closes valve J, shutting off the passage for escape of air ; the pressure in chamber then rises to the point at which valves K open, and some water flows into air vessel L, from which it is constantly flowing out through delivery pipe M. A little air still remains in the chamber at the instant when valve J closes. This air is compressed, enters the air vessel, and is used to drive the motor which actuates the main valve. The column of water in flow pipe is thus brought to rest entirely by elastic resistance of

r—continued.

air. When it has ceased to flow, the main valve is again opened, the water with which the chamber F is now full escapes, the air valve J falls open, admitting atmospheric air, and the water again begins to flow and to escape through valve C. The machine in action is exceedingly smooth and regular; and the useful effect is greater than has ever been attained in the application of water-power to raising water. Besides economy, the system has the following incidental advantages. The water may be used with high pressure even at the highest points of ground to be sluiced, and available pressure for hydraulicing is not limited by the topographical features of the country. At the point where the machines are erected, a large extra supply of water is available besides that at high pressure, and greatly helps to keep the tail-flume clear. Efficiency is 70 per cent. A head of water varying from 10 to 40 ft. has been used, and there appears no reason why these machines should not work equally well with heads varying from 2 to 100 ft. They will work with water carrying in suspense large quantities of earth, gravel and stones, floating sticks and chips, and no obstruction is caused. Considerable variation of head and of quantity of supply, even during working, does not affect the efficiency; and if these factors vary inversely at the same time, as they usually do, the quantity and pressure of water pumped remain the same. The air-vessel is very easily charged with air to any required pressure by the direct action of the water.

TRANSMITTING POWER.

BY WIRE ROPE.

Table 21.—Iron Wire Rope, 6-strand, 7 wires. (Stahl.)

Trade No.	Diameter.	Price per ft.	Estimated Weight per ft. in lb.	Breaking Stress, in tons of 2000 lb.	Proper Working Load in tons of 2000 lb.
	in.	s. d.			
11	1½	2 0	3·37	36·0	9
12	1⅜	1 7½	2·77	30·0	7½
13	1¼	1 5	2·28	25·0	6¼
14	1⅛	1 1½	1·82	20·0	5
15	1	0 11½	1·50	16·0	4
16	⅞	0 9½	1·12	12·3	3
17	¾	0 7	0·88	8·8	2½
18	11/16	0 6	0·70	7·6	2
19	⅝	0 5½	0·57	5·8	1½
20	9/16	0 4	0·41	4·1	1
21	½	0 3½	0·31	2·83	¾
22	7/16	0 2¾	0·23	2·13	½
23	⅜	0 2½	0·19	1·65	
24	5/16	0 2	0·16	1·38	
25	9/32	0 1¾	0·125	1·03	

Table 22.—Special Cast-steel Wire Rope, 6-strand, 7 wires. (Stahl.)

Trade No.	Diameter.	Price per ft.	Estimated Weight per ft. in lb.	Breaking Stress, in tons of 2000 lb.	Proper Working Load in tons of 2000 lb.
	in.	s. d.			
11	1½	2 11	3·37	88·38	22·0
12	1⅜	2 6	2·77	67·20	16·8
13	1¼	2 1	2·28	60·67	15·2
14	1⅛	1 8	1·82	39·84	10·0
15	1	1 4	1·50	31·82	8·0
16	⅞	1 0½	1·12	24·70	6·2
17	¾	0 9½	0·88	18·48	4·6
18	11/16	0 8	0·70	16·32	4·0
19	⅝	0 7	0·57	12·44	3·1
20	9/16	0 5¼	0·41	9·33	2·3
21	½	0 4	0·31	6·89	1·7
22	7/16	0 3¾	0·28	5·23	1·3
23	⅜	0 3¼	0·19	3·93	1·0
24	5/16	0 2½	0·16	3·25	0·81
25	9/32	0 2¼	0·125	2·96	0·75

TRANSMITTING POWER: *Ropes.* (Nystrom.)

In the accompanying Tables (23–35) *Column* D contains the minimum diameter of pulley, wheel, or drum that should be used for the maximum diameter of rope in the next column, *d*. The pulley may be made larger for the same size or smaller rope, and the larger the better for the rope. The heading of each column explains the contents.

The wear of a rope is proportionate to its stiffness—that is, as the cube d^3 of its diameter, and inversely as the square D^2 of the diameter of the pulley.

$$\text{Wear of rope} = \frac{d^3}{D^2},$$

d = diameter in in. of the rope, and D = diameter in ft. of the pulley.

Column Φ contains the stiffness of the rope in lb. for both winding and unwinding on each pulley; when the rope runs over a number of pulleys, as when power is transmitted for long distances, the stiffness must be added for each pulley.

The dynamics of transmission of power by belting, ropes, or chains is calculated by the formulas for circular motion.

The circumference of a rope, as practically measured by a tape-line, is not 3·14 times the diameter of the rope, but is considerably less, depending upon the number of strands in the rope.

d = diameter and c = circumference of the rope.

Two strands	.. ..	$\pi = 2{\cdot}57.$	$c = 2{\cdot}57\,d.$
			$d = 0{\cdot}389\,c.$
Three strands	.. ..	$\pi = 2{\cdot}86.$	$c = 2{\cdot}86\,d.$
			$d = 0{\cdot}35\,c.$
Four strands	.. ..	$\pi = 2{\cdot}96.$	$c = 2{\cdot}96\,d.$
			$d = 0{\cdot}338\,c.$
Seven strands	.. ..	$\pi = 3.$	$c = 3\,d.$

The diameter of the rope is that of the circle tangenting the strands, whilst the circumference is the sum of the lines drawn between the strands.

The accompanying Tables (23–35) were deduced from experiments specially made by Nystrom for his well-known 'Mechanical Engineers' Pocket-book.'

Table 23.—TRANSMITTING POWER: *Horse-power of Iron and Steel Ropes.*

Iron. Diam.	Velocity of Rope in ft. per Second.										Steel. Diam.
	10	20	30	40	50	60	70	80	90	100	
in.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	in.
1/4	4	8	12	16	20	24	28	32	36	40	3/16
5/16	6	12	18	25	31	37	43	50	56	62	1/4
3/8	9	18	27	36	45	54	63	72	81	90	5/16
7/16	12	24	36	49	61	73	85	98	101	122	3/8
1/2	16	32	48	64	80	96	112	128	144	160	3/8
9/16	20	40	60	81	101	121	141	162	182	202	7/16
5/8	25	50	75	100	125	150	175	200	225	250	1/2
11/16	30	60	90	121	151	181	211	242	272	302	9/16
3/4	36	72	108	144	180	216	252	288	324	360	9/16
13/16	42	84	126	169	211	253	295	338	380	422	5/8
7/8	49	98	147	196	245	294	343	392	441	490	11/16
15/16	56	112	168	225	281	337	393	450	506	562	3/4
1	64	128	192	256	320	384	448	512	576	640	13/16
1 1/8	81	162	243	324	405	486	567	648	729	810	7/8
1 1/4	100	200	300	400	500	600	700	800	900	1000	1
1 3/8	121	242	363	484	605	726	847	968	1089	1210	1 1/8
1 1/2	144	288	432	576	720	864	1008	1152	1296	1440	1 3/16
1 5/8	169	338	507	676	845	1014	1183	1352	1521	1690	1 1/4
1 3/4	196	392	588	784	980	1176	1372	1568	1764	1960	1 3/8
1 7/8	225	450	675	900	1125	1350	1575	1800	2025	2250	1 1/2
2	256	512	768	1024	1280	1536	1792	2048	2304	2560	1 9/16
2 1/4	324	648	974	1296	1620	1944	2268	2602	2916	3240	1 3/4
2 1/2	400	800	1200	1600	2000	2400	2800	3200	3600	4000	2
2 3/4	484	968	1452	1936	2420	2904	3388	3882	4356	4840	2 3/16
3	576	1152	1728	2304	2880	3456	4032	4608	5184	5760	2 1/2

Table 24.—TRANSMITTING POWER: *Hemp Rope, white, 3 strands.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
21·0	6	17·1	324,000	81,000	9·4	·1064	7·6	12·7
19·0	5½	15·7	272,000	68,000	7·9	·1266	6·6	11·0
16·5	5	14·25	225,000	56,250	6·52	·1533	6·0	10·0
14·0	4¼	12·1	182,000	45,500	5·28	·1894	5·4	9·0
12·0	4	11·4	144,000	36,000	4·18	·2392	4·6	7·7
11·0	3¾	10·7	126,000	31,500	3·67	·2725	4·2	7·0
10·0	3½	10·0	110,000	27,500	3·2	·3125	3·9	6·5
9·0	3¼	9·27	95,000	23,750	2·76	·3613	3·6	6·0
8·0	3	8·57	81,000	20,250	2·35	·4255	3·36	5·6
7·0	2¾	7·85	68,000	17,000	1·97	·5076	3·05	5·1
6·0	2½	7 14	56,200	14,050	1·63	·6135	2·82	4·7
5·25	2¼	6·43	45,500	11,375	1·32	·7575	2·4	4·0
4·25	2	5·70	36,000	9,000	1·04	·9615	2·25	3·75
3·4	1¾	5·00	27,500	6,875	0·80	1·25	2·1	3·5
2·75	1½	4·28	20,200	5,050	0·588	1·700	1·74	2·9
2·1	1⅜	3·97	14,000	3,500	0·407	2·457	1·44	2·4
1·5	1	2·86	9,000	2,250	0·261	3·831	1·16	1·93
1·22	⅞	2·5	6,900	1,725	0·200	5·000	1·02	1·7
0·97	¾	2·14	5,050	1,262	0·147	6·803	0·87	1·46
0·74	⅝	1·78	3,500	875	0·102	9·803	0·72	1·21
0·53	½	1·43	2,240	560	0·065	15·38	0·58	0·97
0·34	⅜	1·07	1,260	315	0·036	27·77	0·45	0·75
0·18	¼	0·71	560	140	0·016	62·50	0·31	0·52

Table 25.—TRANSMITTING POWER: *Manilla Ropes, 3 strands.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
26·4	6	17·1	216,000	54,000	8·64	·1157	5·37	8·87
23·2	5½	15·7	181,500	45,375	7·26	·1377	5·00	8·26
20·0	5	14·25	150,000	37,500	6·00	·1666	4·5	7·45
17·2	4½	12·1	121,000	30,250	4·86	·2057	4·00	6·62
14·4	4	11·4	96,000	24,000	3·84	·2604	3·57	5·9
13·0	3¾	10·7	84,400	21,100	3·38	·2958	3·37	5·56
11·8	3½	10·0	73,600	18,400	2·94	·3401	3·10	5·15
10·5	3¼	9·27	63,500	15,875	2·53	·3952	2·93	4·85
9·35	3	8·57	54,000	13,500	2·16	·4629	2·68	4·43
8·2	2¾	7·85	45,400	11,350	1·81	·5524	2·45	4·06
7·1	2½	7·14	37,500	9,375	1·5	·6666	2·24	3·70
6·0	2¼	6·43	30,400	7,600	1·21	·8264	2·06	3·4
5·0	2	5·70	24,000	6,000	0·96	1·041	1·85	3·07
4·0	1¾	5·00	18,400	4,600	0·725	1·379	1·700	2·8
3·3	1½	4·28	13,500	3,350	0·54	1·852	1·40	2·32
2·5	1¼	3·57	9,380	2,345	0·375	2·666	1·11	1·84
1·8	1	2·86	6,000	1,500	0·24	4·166	0·8870	1·47
1·46	⅞	2·5	4,600	1,150	0·184	5·435	0·894	1·31
1·17	¾	2·14	3,380	845	0·135	7·407	0·6666	1·10
0·89	⅝	1·78	2,350	587	0·093	10·75	0·558	0·92
0·63	½	1·43	1,500	375	0·060	16·66	0·454	0·75
0·41	⅜	1·07	845	211	0·033	30·30	0·36	0·56
0·22	¼	0·71	375	93	0·015	66·66	0·23	0·38

Table 26.—TRANSMITTING POWER: *Tarred Hemp Ropes, 4 strands.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	d	c	S	T	w	l	Φ	Φ
36·0	6	18	230,000	57,500	15·1	·0662	13·3	18·9
32·0	5½	16½	194,000	48,500	12·7	·0784	12·0	17·0
28·0	5	15	160,000	40,000	10·5	·0952	10·6	15·1
24·0	4½	13½	130,000	32,500	8·52	·1174	9·5	13·5
20·0	4	12	102,500	25,625	6·72	·1488	8·5	12·1
18·0	3¾	11¼	90,000	22,500	5·92	·1689	8·1	11·5
16·0	3½	10½	78,500	19,625	5·16	·1938	7·8	11·1
14·6	3¼	9¾	67,700	16,925	4·44	·2252	7·0	10·0
12·9	3	9	57,700	14,425	3·78	·2645	6·46	9·2
11·4	2¾	8¼	48,400	12,100	3·18	·3144	5·83	8·3
9·9	2½	7½	40,000	10,000	2·63	·3802	5·27	7·5
8·4	2¼	6¾	32,400	8,100	2·13	·4695	4·83	6·87
7·0	2	6	25,600	6,400	1·68	·5952	4·34	6·18
5·8	1¾	5¼	19,600	4,900	1·29	·7752	3·70	5·26
4·6	1½	4½	14,400	3,600	0·945	1·058	3·18	4·53
3·5	1¼	3¾	10,000	2,500	0·656	1·524	2·64	3·76
2·5	1	3	6,400	1,600	0·420	2·381	2·13	3·03
2·0	⅞	2⅝	4,900	1,225	0·322	3·105	1·95	2·78
1·6	¾	2¼	3,600	900	0·236	4·237	1·64	2·34
1·2	⅝	1⅞	2,500	625	0·164	6·097	1·40	2·00
0·9	½	1½	1,600	400	0·105	9·523	1·02	1·46
0·58	⅜	1⅛	900	225	0·059	16·95	0·77	1·10
0·31	¼	¾	400	100	0·026	38·46	0·53	0·76

Table 27.—TRANSMITTING POWER: *Cotton Ropes, 3 strands of Fine Yarns.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	d	c	S	T	w	l	Φ	Φ
14·7	6	18	18,000	4,500	7·20	0·1389	4·0	6·0
12·9	5⅓	16½	15,125	3,781	6·05	0·1653	3·68	5·5
11·2	5	15	12,500	3,125	5·00	0·2000	3·3	5·0
9·5	4½	13½	10,125	2,531	4·05	0·2469	3·0	4·5
8 0	4	12	8,000	2,000	3·20	0·3125	2·66	4·0
7·2	3¾	11¼	7,030	1,782	2·81	0·3559	2·55	3·83
6·5	3½	10½	6,125	1,531	2·45	0·4082	2·37	3·56
5·8	3¼	9¾	5,281	1,320	2·11	0·4739	2·22	3·33
5·2	3	9	4,500	1,125	1·80	0·5555	2·0	3·0
4·5	2¾	8¼	3,781	945	1·52	0·6579	1·89	2·84
4·0	2½	7½	3,125	781	1·25	0·8000	1·63	2·45
3·4	2¼	6¾	2,531	633	1·01	0·9901	1·48	2·23
2·8	2	6	2,000	500	0·80	1·250	1·36	2·05
2·3	1¾	5¼	1,531	383	0·61	1·639	1·18	1·78
1·8	1½	4½	1,125	281	0·45	2·222	1·04	1·58
1·4	1¼	3¾	781	195	0·31	3·226	0·83	1·25
1·0	1	3	500	125	0·20	5·000	0·66	1·0
0·82	⅞	2⅝	383	96	0·15	6·666	0·59	0·89
0·65	¾	2¼	281	70	0·11	9·009	0·5	0·75
0·5	⅝	1⅞	195	49	0·078	12·82	0·4	0·61
0·35	½	1½	125	31	0·05	20·00	0·34	0·51
0·23	⅜	1⅛	70	17	0·028	35·71	0·25	0·37
0·125	¼	¾	31	8	0·012	83·33	0·16	0·25

Table 28.—TRANSMITTING POWER: *Iron Ropes.* 19 × 7 = 133 *Wires and Wire Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
41·6	3	9	300,000	75,000	16·83	·0594	5·4	7·4
36·5	$2\frac{3}{4}$	$8\frac{1}{4}$	252,500	63,125	12·45	·0803	4·95	6·8
31·5	$2\frac{1}{2}$	$7\frac{1}{2}$	209,000	51,250	10·3	·0971	4·54	6·24
27·0	$2\frac{1}{4}$	$6\frac{3}{4}$	169,000	42,250	8·34	·1199	4·06	5·58
22·6	2	6	133,000	33,250	6·62	·1510	3·60	4·97
20·5	$1\frac{7}{8}$	$5\frac{5}{8}$	117,500	29,375	5·78	·1730	3·37	4·64
18·5	$1\frac{3}{4}$	$5\frac{1}{4}$	102,000	25,500	5·04	·1984	3·15	4·34
16·5	$1\frac{5}{8}$	$4\frac{7}{8}$	88,400	21,100	4·35	·2299	2·95	4·05
14·75	$1\frac{1}{2}$	$4\frac{1}{2}$	75,200	18,800	3·70	·2703	2·65	3·64
13·0	$1\frac{3}{8}$	$4\frac{1}{8}$	63,200	15,800	3·12	·3205	2·42	3·33
11·2	$1\frac{1}{4}$	$3\frac{3}{4}$	52,200	13,050	2·57	·3891	2·22	3·06
9·55	$1\frac{1}{8}$	$3\frac{3}{8}$	42,300	10,575	2·08	·4807	1·91	2·77
8·0	1	3	33,300	8,325	1·65	·6061	1·80	2·47
6·56	$\frac{7}{8}$	$2\frac{5}{8}$	25,600	6,400	1·26	·7936	1·56	2·15
5·2	$\frac{3}{4}$	$2\frac{1}{4}$	18,800	4,700	0·927	1·078	1·34	1·85
3·96	$\frac{5}{8}$	$1\frac{7}{8}$	13,000	3,250	0·644	1·553	1·11	1·54
2·83	$\frac{1}{2}$	$1\frac{1}{2}$	8,360	2,090	0·412	2·427	0·90	1·23
2·31	$\frac{7}{16}$	$1\frac{5}{16}$	6,400	1,600	0·315	3·174	0·79	1·09
1·83	$\frac{3}{8}$	$1\frac{1}{8}$	4,710	1,177	0·231	4·329	0·68	0·93
1·4	$\frac{5}{16}$	$\frac{15}{16}$	2,270	812	0·160	6·250	0·55	0·76
1·0	$\frac{1}{4}$	$\frac{3}{4}$	2,090	522	0·102	9·804	0·44	0·61
0·65	$\frac{3}{16}$	$\frac{9}{16}$	1,180	295	0·057	17·54	0·33	0·46
0·35	$\frac{1}{8}$	$\frac{3}{8}$	522	130	0·025	40·00	0·23	0·32

Table 29.—TRANSMITTING POWER: *Iron Ropes.* 19 × 6 = 114 *Wires and Hemp Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	c	S	T	*w*	*l*	Φ	Φ
31·0	3	9	287,500	71,875	13·5	·0741	7·2	10·1
27·0	2¾	8¼	241,500	60,375	11·3	·0885	6·77	9·46
23·7	2½	7½	200,000	50,000	9·36	·1068	6·09	8·51
20·0	2¼	6¾	161,500	40,750	7·60	·1316	5·51	7·71
17·0	2	6	128,000	32,000	6·02	·1661	4·75	6·65
15·4	1⅞	5⅝	112,000	28,000	5·27	·1807	4·47	6·25
14·0	1¾	5¼	98,000	24,500	4·58	·2183	4·11	5·75
12·4	1⅝	4⅞	84,400	21,100	3·96	·2525	3·90	5·45
11·0	1½	4½	72,000	18,000	3·37	·2967	3·66	5·12
9·7	1⅜	4⅛	60,400	15,100	2·83	·3533	3·25	4·55
7·8	1¼	3¾	50,000	12,500	2·34	·4273	2·96	4·13
7·1	1⅛	3⅜	40,400	10,100	1·89	·5291	2·73	3·82
6·0	1	3	32,000	8,000	1·50	·6666	2·39	3·34
5·0	⅞	2⅝	24,250	6,062	1·14	·8772	2·00	2·81
4·0	¾	2¼	18,000	4,500	0·844	1·184	1·70	2·38
3·0	⅝	1⅞	12,500	3,125	0·586	1·706	1·45	2·03
2·1	½	1½	8,000	2,000	0·375	2·666	1·22	1·70
1·7	$\frac{7}{16}$	$1\frac{5}{16}$	6,120	1,530	0·287	3·484	1·09	1·52
1·3	⅜	1⅛	4,500	1,125	0·211	4·739	1·01	1·41
1·0	$\frac{5}{16}$	$\frac{15}{16}$	3,129	780	0·146	6·849	0·81	1·14
0·75	¼	¾	2,000	500	0·093	10·75	0·59	0·83
0·5	$\frac{3}{16}$	$\frac{9}{16}$	1,120	280	0·052	19·23	0·42	0·60
0·27	⅛	⅜	500	125	0·023	43·48	0·29	0·41

Table 30.—TRANSMITTING POWER: *Iron Ropes.* 7 × 7 = 49 *Wires and Wire Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
62·5	3	9	300,000	75,000	16·83	·0594	8·8	12·1
54·5	$2\frac{3}{4}$	$8\frac{1}{4}$	252,500	63,125	12·45	·0803	7·9	10·9
47·0	$2\frac{1}{2}$	$7\frac{1}{2}$	209,000	51,250	10·3	·0971	7·45	10·2
40·0	$2\frac{1}{4}$	$6\frac{3}{4}$	169,000	42,250	8·34	·1199	6·8	9·30
34·0	2	6	133,000	33,250	6·62	·1510	5·86	8·04
30·0	$1\frac{7}{8}$	$5\frac{5}{8}$	117,500	29,375	5·78	·1730	5·60	7·68
27·0	$1\frac{3}{4}$	$5\frac{1}{4}$	102,000	25,500	5·04	·1984	5·30	7·26
25·0	$1\frac{5}{8}$	$4\frac{7}{8}$	88,400	44,100	4·35	·2299	4·72	6·48
22·0	$1\frac{1}{2}$	$4\frac{1}{2}$	75,200	18,800	3·70	·2703	4·41	6·05
19·0	$1\frac{3}{8}$	$4\frac{1}{8}$	63,200	15,800	3·12	·3205	4·18	5·74
16·5	$1\frac{1}{4}$	$3\frac{3}{4}$	52,200	18,050	2·57	·3891	3·78	5·19
14·0	$1\frac{1}{8}$	$3\frac{3}{8}$	42,300	10,575	2·08	·4807	3·45	4·74
12·0	1	3	33,300	8,325	1·65	·6061	2·93	4·03
10·0	$\frac{7}{8}$	$2\frac{5}{8}$	25,600	6,400	1·26	·7936	2·48	3·40
8·0	$\frac{3}{4}$	$2\frac{1}{4}$	18,800	4,700	0·927	1·078	2·05	2·82
6·0	$\frac{5}{8}$	$1\frac{7}{8}$	13,000	3,250	0·644	1·553	1·79	2·46
4·25	$\frac{1}{2}$	$1\frac{1}{2}$	8,360	2,090	0·412	2·427	1·53	2·10
3·5	$\frac{7}{16}$	$1\frac{5}{16}$	6,400	1,600	0·315	3·174	1·26	1·73
2·75	$\frac{3}{8}$	$1\frac{1}{8}$	4,710	1,177	0·231	4·329	1·10	1·52
2·1	$\frac{5}{16}$	$\frac{15}{16}$	3,270	812	0·160	6·250	0·91	1·25
1·5	$\frac{1}{4}$	$\frac{3}{4}$	2,090	522	0·102	9·804	0·73	1·00
1·0	$\frac{3}{16}$	$\frac{9}{16}$	1,180	295	0·057	17·54	0·52	0·72
0·5	$\frac{1}{8}$	$\frac{3}{8}$	522	130	0·025	40·00	0·4	0·56

Table 31.—TRANSMITTING POWER: *Iron Ropes.* 7 × 6 = 42 *Wires and Hemp Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
52·0	3	9	287,500	71,875	13·5	·0741	5·00	7·02
45·0	$2\frac{3}{4}$	$8\frac{1}{4}$	241,500	60,375	11·3	·0885	4·72	6·62
39·0	$2\frac{1}{2}$	$7\frac{1}{2}$	200,000	50,000	9·36	·1068	4·26	6·00
34·0	$2\frac{1}{4}$	$6\frac{3}{4}$	161,500	40,750	7·60	·1316	3·72	5·21
28·0	2	6	128,000	32,000	6·02	·1661	3·43	4·81
25·0	$1\frac{7}{8}$	$5\frac{5}{8}$	112,000	28,000	5·27	·1807	3·17	4·44
23·0	$1\frac{3}{4}$	$5\frac{1}{4}$	98,000	24,500	4·58	·2183	2·93	4·12
21·0	$1\frac{5}{8}$	$4\frac{7}{8}$	84,400	21,100	3·96	·2525	2·64	3·70
18·0	$1\frac{1}{2}$	$4\frac{1}{2}$	72,000	18,000	3·37	·2967	2·5	3·49
16·0	$1\frac{3}{8}$	$4\frac{1}{8}$	60,400	15,100	2·83	·3533	2·33	3·27
14·0	$1\frac{1}{4}$	$3\frac{3}{4}$	50,000	12,500	2·34	·4273	2·10	2·95
12·0	$1\frac{1}{8}$	$3\frac{3}{8}$	40,400	10,100	1·89	·5291	1·85	2·60
10·0	1	3	32,000	8,000	1·50	·6666	1·60	2·34
8·2	$\frac{7}{8}$	$2\frac{5}{8}$	24,250	6,062	1·14	·8772	1·45	2·04
6·5	$\frac{3}{4}$	$2\frac{1}{4}$	18,000	4,500	0·844	1·184	1·25	1·75
5·0	$\frac{5}{8}$	$1\frac{7}{8}$	12,500	3,125	0·586	1·706	1·02	1·43
3·5	$\frac{1}{2}$	$1\frac{1}{2}$	8,000	2,000	0·375	2·666	0·85	1·20
3·0	$\frac{7}{16}$	$1\frac{5}{16}$	6,120	1,530	0·287	3·484	0·67	0·95
2·3	$\frac{3}{8}$	$1\frac{1}{8}$	4,500	1,125	0·211	4·739	0·62	0·87
1·7	$\frac{5}{16}$	$\frac{15}{16}$	3,120	780	0·146	6·849	0·55	0·77
1·25	$\frac{1}{4}$	$\frac{3}{4}$	2,000	500	0·093	10·75	0·41	0·58
0·8	$\frac{3}{16}$	$\frac{9}{16}$	1,120	280	0·052	19·23	0·32	0·45
0·4	$\frac{1}{8}$	$\frac{3}{8}$	500	125	0·023	43·48	0·25	0·35

Table 32.—TRANSMITTING POWER: *Iron Rope.* 7 × 6 × 6 = 252 *Wires.* *Cotton Centre in each Rope Strand and Hemp in the Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
21·0	3	9	270,000	67,500	12·2	·0819	5·40	7·80
18·0	$2\frac{3}{4}$	$8\frac{1}{4}$	226,500	56,625	10·2	·0980	4·88	7·04
16·0	$2\frac{1}{2}$	$7\frac{1}{2}$	187,000	46,750	8·57	·1167	4·40	6·37
13·5	$2\frac{1}{4}$	$6\frac{3}{4}$	152,000	38,000	6·84	·1462	3·98	5·74
11·0	2	6	120,000	30,000	5·42	·1845	3·74	5·39
10·0	$1\frac{7}{8}$	$5\frac{5}{8}$	105,400	26,350	4·76	·2101	3·50	5·03
9·0	$1\frac{3}{4}$	$5\frac{1}{4}$	91,700	22,925	4·13	·2421	3·26	4·70
8·0	$1\frac{5}{8}$	$4\frac{7}{8}$	79,000	19,750	3·56	·2809	3·08	4·44
7·0	$1\frac{1}{2}$	$4\frac{1}{2}$	67,500	16,875	3·04	·3289	2·87	4·14
6·25	$1\frac{3}{8}$	$4\frac{1}{8}$	56,600	14,250	2·55	·3921	2·58	3·72
5·5	$1\frac{1}{4}$	$3\frac{3}{4}$	46,800	11,700	2·11	·4739	2·30	3·30
4·75	$1\frac{1}{8}$	$3\frac{3}{8}$	38,000	9,500	1·71	·5848	2·00	2·90
4·0	1	3	30,000	7,500	1·35	·7407	1·77	2·55
3·25	$\frac{7}{8}$	$2\frac{5}{8}$	23,000	5,750	1·03	·9709	1·57	2·27
2·6	$\frac{3}{4}$	$2\frac{1}{4}$	16,850	4,212	0·760	1·316	1·32	1·91
2·0	$\frac{5}{8}$	$1\frac{7}{8}$	11,700	2,925	0·528	1·894	1·09	1·57
1·4	$\frac{1}{2}$	$1\frac{1}{2}$	7,500	1,875	0·338	2·958	0·90	1·30
1·15	$\frac{7}{16}$	$1\frac{5}{16}$	5,740	1,435	0·258	3·876	0·79	1·14
0·9	$\frac{3}{8}$	$1\frac{1}{8}$	4,220	1,055	0·190	5·263	0·69	1·00
0·7	$\frac{5}{16}$	$\frac{15}{16}$	2,930	732	0·132	7·576	0·55	0·80
0·5	$\frac{1}{4}$	$\frac{3}{4}$	1,870	467	0·084	11·90	0·44	0·64
0·3	$\frac{3}{16}$	$\frac{9}{16}$	1,050	262	0·047	21·27	0·38	0·56
0·18	$\frac{1}{8}$	$\frac{3}{8}$	468	117	0·021	47·62	0·20	0·30

Table 33.—TRANSMITTING POWER: *Cast Steel Ropes.* 19 × 7 = 133 *Wires and Wire Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
50·0	3	9	486,000	121,500	16·83	·0594	9·37	11·7
45·0	2¾	8¼	416,000	104,000	12·45	·0803	8·19	10·2
38·7	2½	7½	344,000	86,000	10·3	·0971	7·59	9·45
33·0	2¼	6¾	279,000	69,750	8·34	·1199	6·84	8·52
27·7	2	6	220,000	55,000	6·62	·1510	6·36	7·92
25·0	1⅞	5⅝	193,500	48,375	5·78	·1730	5·73	7·15
22·7	1¾	5¼	168,500	42,125	5·04	·1984	5·28	6·58
20·3	1⅝	4⅞	145,500	36,375	4·35	·2299	4·87	6·08
18·0	1½	4½	123,500	30,875	3·70	·2703	4·52	5·63
15·8	1⅜	4⅛	104,000	26,000	3·12	·3205	4·12	5·13
13·7	1¼	3¾	86,000	21,500	2·57	·3891	3·77	4·70
11·7	1⅛	3⅜	69,600	17,400	2·08	·4807	3·39	4·23
9·8	1	3	55,000	13,750	1·65	·6061	3·00	3·75
8·0	⅞	2⅝	42,200	10,550	1·26	·7936	2·65	3·30
6·4	¾	2¼	31,000	7,750	0·927	1·078	2·24	2·79
4·87	⅝	1⅞	21,500	5,375	0·644	1·553	1·87	2·33
3·46	½	1½	13,750	3,687	0·412	2·427	1·51	1·89
2·84	$\frac{7}{16}$	1$\frac{5}{16}$	10,500	2,625	0·315	3·174	1·32	1·65
2·25	⅜	1⅛	7,740	1,935	0·231	4·329	1·13	1·41
1·71	$\frac{5}{16}$	$\frac{15}{16}$	5,380	1,345	0·160	6·250	0·94	1·18
1·22	¼	¾	3,440	860	0·102	9·804	0·75	0·94
0·8	$\frac{3}{16}$	$\frac{9}{16}$	1,935	484	0·057	17·54	0·56	0·70
0·433	⅛	⅜	860	215	0·025	40·00	0·38	0·48

Table 34.—TRANSMITTING POWER: *Cast Steel Ropes.* 19 × 6 = 114 *Wires and Hemp Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	d	c	S	T	w	l	Φ	Φ
41·6	3	9	432,000	108,000	13·5	·0741	6·0	8·25
36·5	$2\frac{3}{4}$	$8\frac{1}{4}$	363,000	90,750	11·3	·0885	5·45	7·50
31·5	$2\frac{1}{2}$	$7\frac{1}{2}$	300,000	75,000	9·36	·1068	5·04	6·93
27·0	$2\frac{1}{4}$	$6\frac{3}{4}$	243,000	67,500	7·60	·1316	4·51	6·20
22·6	2	6	192,000	48,000	6·02	·1661	4·00	5·49
20·5	$1\frac{7}{8}$	$5\frac{5}{8}$	168,500	42,125	5·27	·1807	3·77	5·18
18·5	$1\frac{3}{4}$	$5\frac{1}{4}$	146,500	36,625	5·08	·2183	3·50	4·82
16·5	$1\frac{5}{8}$	$4\frac{7}{8}$	126,500	31,625	3·96	·2525	3·27	4·50
14·75	$1\frac{1}{2}$	$4\frac{1}{2}$	108,000	27,000	3·37	·2967	2·98	4·10
13·0	$1\frac{3}{8}$	$4\frac{1}{8}$	90,700	22,675	2·83	·3533	2·70	3·72
11·2	$1\frac{1}{4}$	$3\frac{3}{4}$	75,000	18,750	2·34	·4273	2·50	3·43
9·55	$1\frac{1}{8}$	$3\frac{3}{8}$	60,700	15,175	1·89	·5291	2·24	3·08
8·0	1	3	48,000	12,000	1·50	·6666	2·00	2·76
6·56	$\frac{7}{8}$	$2\frac{5}{8}$	36,800	9,200	1·14	·8772	1·74	2·40
5·2	$\frac{3}{4}$	$2\frac{1}{4}$	27,000	6,750	0·844	1·184	1·50	2·06
3·96	$\frac{5}{8}$	$1\frac{7}{8}$	18,750	4,687	0·586	1·706	1·24	1·71
2·83	$\frac{1}{2}$	$1\frac{1}{2}$	12,000	3,000	0·375	2·666	1·00	1·38
2·31	$\frac{7}{16}$	$1\frac{5}{16}$	9,200	2,300	0·287	3·484	0·88	1·21
1·83	$\frac{3}{8}$	$1\frac{1}{8}$	6,750	1,687	0·211	4·739	0·75	1·04
1·4	$\frac{5}{16}$	$\frac{15}{16}$	4,680	1,170	0·146	6·849	0·61	0·85
1·0	$\frac{1}{4}$	$\frac{3}{4}$	3,000	750	0·093	10·75	0·49	0·68
0·65	$\frac{3}{16}$	$\frac{9}{16}$	1,685	421	0·052	19·23	0·37	0·51
0·35	$\frac{1}{8}$	$\frac{3}{8}$	750	187	0·023	43·48	0·24	0·33

Table 35.—TRANSMITTING POWER: *Copper Ropes.* $7 \times 6 = 42$ *Wires.* *Cotton Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	*d*	*c*	S	T	*w*	*l*	Φ	Φ
26·0	3	9	306,000	76,500	15·25	·0656	9·60	13·4
22·5	2¾	8¼	257,000	64,250	12·9	·0775	9·00	12·6
20·0	2½	7½	212,500	53,125	10·6	·0943	8·50	11·9
17·0	2¼	6¾	172,000	43,000	8·44	·1185	7·14	10·0
14·0	2	6	136,000	34,000	6·82	·1466	6·44	9·0
12·5	1⅞	5⅝	120,000	30,000	5·97	·1675	6·16	8·6
11·5	1¾	5¼	104,000	26,000	5·20	·1923	5·43	7·8
10·5	1⅝	4⅞	90,000	22,500	4·48	·2232	5·00	7·0
9·0	1½	4½	76,500	19,125	3·82	·2618	4·70	6·1
8·0	1⅜	4⅛	64,200	16,050	3·21	·3115	4·44	5·70
7·0	1¼	3¾	53,100	13,275	2·88	·3472	3·96	5·30
6·0	1⅛	3⅜	42,800	10,700	2·15	·4651	3·50	4·90
5·0	1	3	34,000	8,500	1·70	·5882	3·22	4·50
4·0	⅞	2⅝	26,000	6,500	1·30	·7692	2·94	4·10
3·25	¾	2¼	19,100	4,775	0·956	1·046	2·44	3·42
2·5	⅝	1⅞	13,250	3,312	0·673	1·486	1·83	2·70
1·75	½	1½	8,500	2,125	0·424	2·358	1·65	2·30
1·5	$\frac{7}{16}$	$1\frac{3}{16}$	6,510	1,627	0·325	3·077	1·29	1·80
1·15	⅜	1⅛	4,780	1,195	0·239	4·184	1·20	1·67
0·85	$\frac{5}{16}$	$\frac{13}{16}$	3,320	830	0·166	6·024	1·05	1·47
0·62	¼	¾	2,120	530	0·106	9·433	0·81	1·13
0·4	$\frac{3}{16}$	$\frac{9}{16}$	1,200	300	0·059	16·95	0·62	0·87
0·2	⅛	⅜	530	132	0·026	38·46	0·48	0·67

ROPE DRIVING. (C. W. Hunt.)

It has been found that 200 lb. on a 1-in. rope is a safe and economical working load, and when materially increased the wear is rapid. Test pieces of manilla rope made at different works varied slightly in diameter, but when reduced to the equivalent of 1 in. diameter had an average breaking strength of 7140 lb. Expressed algebraically, the breaking strength, weight per foot, and the working strains are—

$$W = 720\ C^2\ (1);\ P = \cdot 32\ C^2\ (2);\ w = 20\ C^2\ (1)$$

In these and the following equations:—

C = circumference of rope in inches.
D = sag of the rope in inches.
F = centrifugal force in lb.
g = gravity.
H = horse-power.
L = distance between pulleys in ft.
P = lb. per ft. of rope.
R = force in lb. doing useful work.
S = load in lb. on rope at pulley.
T = tension in lb. on driving side of the rope.
t = tension in lb. on slack side of the rope.
v = velocity of rope in ft. per second.
w = working load in lb.
W = ultimate breaking load in lb.

This makes the normal working load equal to $\frac{1}{36}$ the breaking strength, and about $\frac{1}{25}$ of the strength at the splice. The actual loads are ordinarily much greater, owing to the vibrations in running, as well as from imperfectly adjusted tension mechanism.

Assuming that the load on the driving side of a rope is equal to 200 lb. on a rope 1 in. diam., and that the rope is in motion at various velocities of 10 ft. to 140 ft. per second. Then we will have in all cases a fibre load of 200 lb. on the driving side of a 1-in. rope, and an equivalent load for other sizes. The centrifugal force of the rope in running over the pulley will reduce the amount of force available for the transmission of power. The centrifugal force of the rope is computed by the formula—

$$F = \frac{P\,v^2}{g}. \qquad (2)$$

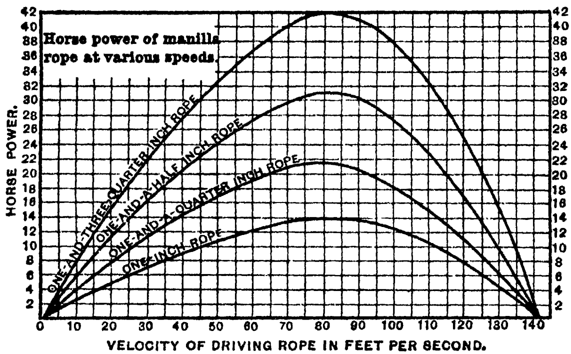
At a speed of about 80 ft. per second, the centrifugal force increases faster than the power from increased velocity of the rope, and about 140 ft. per second equals the assumed allowable tension of the rope. Computing this force at various speeds and then subtracting it from the assumed maximum tension, we have the force available for the transmission of power. The whole of this force

Rope driving—continued.

cannot be used, because a certain amount of tension on the slack side of the rope is needed to given adhesion to the pulley. What tension should be given to the rope for this purpose is uncertain, as there are no experiments which give accurate data, and at the present time a decision must be made partly from analogy and partly from experience.

If the rope be considered as a belt on a plain pulley, the friction would be substantially the same as a leather belt at the same tension; but as ropes are frequently lubricated to reduce the wear,

Fig. 8.



the coefficient of friction must be materially reduced. There have been no experiments to decide with accuracy what this reduction is, but it is known from considerable experience that when the rope runs in a groove whose sides are inclined towards each other at an angle of 45° there is sufficient adhesion when the ratio of the tension is

$$\frac{T}{t} = 2. \qquad (3)$$

For the present purpose T can be divided into three parts:—Tension doing useful work, tension from centrifugal force, tension to balance the strain for adhesion. The tension t can be divided into two parts:—Tension for adhesion, tension from centrifugal force. It is evident, however, that the tension required to do a given work should not be materially exceeded during the life of the rope.

Rope driving—continued.

There are two methods of putting ropes on the pulleys; one in which the ropes are single and spliced on, being made very taut at first, and less so as the rope lengthens, stretching until it slips, when it is respliced. The other method is to wind a single rope over the pulley as many turns as needed to obtain the necessary horse-power, and put a tension pulley to give the necessary adhesion and also to take up the wear. The total tension T on the driving side of the rope is assumed to be the same at all speeds. The centrifugal force, as well as an amount equal to the tension for adhesion on the slack side of the rope, must be taken from the total tension T to ascertain the amount of force available for the transmission of power.

It is assumed that the tension on the slack side necessary for giving adhesion is equal to one-half the force doing useful work on the driving side of the rope; hence the force for useful work is—

$$R = \frac{2(T-F)}{3}, \tag{4}$$

and the tension on the slack side to give the required adhesion is—

$$\frac{(T-F)}{3}. \tag{5}$$

Hence, $$t = \frac{(T-F)}{3} + F. \tag{6}$$

The sum of the tensions T and t is not the same at different speeds, as the equation (6) indicates.

As F varies as the square of the velocity, there is, with an increasing speed of the rope, a decreasing useful force, and an increasing total tension t on the slack side. With these assumptions of allowable stresses, the horse-power will be—

$$H = \frac{2v(T-F)}{3 \times 550}, \tag{7}$$

Transmission ropes are usually 1–1¾ in. diam. A computation of the horse-power for four sizes at various speeds and under ordinary conditions, based on a maximum load equivalent to 200 lb. for a rope 1 in. diam., is given in Fig. 8. The horse-power of other sizes is readily obtained from these. The maximum power is transmitted, under the assumed conditions, at a speed of about 80 ft. per second.

Rope driving—continued.

The first cost of the rope will be smallest when the power transmitted by it is greatest, and, under the assumed conditions, will be a minimum for a given power when the velocity of the rope is about 80 ft. per second. The ratio of the first cost of the rope running at any other speed will be—

$$\text{Ratio of first cost} = \frac{\text{H at 80 ft. per second}}{\text{H at required speed}}. \qquad (8)$$

The wear of the rope is both internal and external; the internal is caused by the movement of the fibres on each other, under pressure in bending over the sheaves, and the external is caused by the slipping and the wedging in the grooves of the pulley. Both of these causes of wear are, within the limits of ordinary practice, assumed to be directly proportional to the speed. Hence, if we assume the coefficient of the wear to be k, the wear will be $k\,v$, in which the wear increases directly as the velocity, but the horse-power that can be transmitted, as equation (7) shows, will not vary at the same rate.

If we divide the value for wear at a given speed by the horse-power that the same rope will transmit at other speeds, we get the relative wear of the rope in transmitting 1 horse-power. The higher the speed, up to about 80 ft. per second, the more power will be transmitted, but it is accompanied by a more than equivalent wear.

The rope is supposed to have the strain T constant at all speeds on the driving side, and in direct proportion to the area of the cross-section; hence the catenary of the driving side is not affected by the speed or by the diameter of the rope.

The deflection of the rope between the pulleys on the slack side varies with each change of the load or change of the speed, as the tension equation (8) indicates. The deflection or sag of the rope may be computed for the assumed value of T and t by the parabolic formula—

$$S = \frac{P\,L^2}{8\,D} + P\,D, \qquad (9)$$

S being the assumed strain T on the driving side, and t, calculated by equation (6), on the slack side.

It is to be regretted that accurate data are not available to determine the constants needed in the equations for wear and for friction on the pulley.

Table 36.—TRANSMITTING POWER: *Comparison of Ropes.*

Locked Wire Rope made of Patent Crucible Steel.		Ordinary Round Wire Rope made of Patent Crucible Steel.			Tarred Hemp Rope.		Working Load for Inclines $\frac{1}{6}$th of Breaking Strain.	Working Load for Shafts $\frac{1}{8}$th of Breaking Strain.	Breaking Strain.
Circumference in inches.	Weight per fathom.	Circumference in inches.	Weight per fathom, rope made entirely of wire.	Weight per fathom, rope made with hemp centre core.	Circumference in inches.	Weight per fathom.			
	lb.		lb.	lb.		lb.	ton. cwt.	ton. cwt.	ton.
5	34	6½	44	38	22	121	19 13	14 15	118
4¾	31	6¼	40	35	21	110	18 6	13 15	110
4½	28	6	37	32	20	100	16 13	12 10	100
4¼	25	5½	30	26	19	91	14 3	10 12	85
4	22	5	25½	23	18	81	12 10	9 7	75
3¾	20	4¾	24	22	17	72	10 16	8 2	65
3½	17½	4½	22	20	15	56	10 0	7 10	60
3¼	15½	4	18½	16½	14	48	8 6	6 5	50
3	13½	3⅞	18¼	15¼	13	42	6 16	5 2	41
2¾	11	3¾	17	14½	12	36	6 6	4 15	38
2½	8½	3½	10¾	9½	11	31	5 0	3 15	30
2¼	7	3	9½	8	10	25	4 3	3 2	25
2	5¾	2⅝	7	6¼	9	20	3 3	2 7	19

Table 37.—TRANSMITTING POWER: *Comparative Efficiency of Systems.* (Beringer.)

Distance of Transmission.	Electric.	Hydraulic.	Pneumatic.	Wire Rope.
300 ft.	·69	·50	·55	·96
1,500 „	·68	·50	·55	·93
3,000 „	·66	·50	·55	·90
15,000 „	·60	·40	·50	·60
30,000 „	·51	·35	·50	·36
60,000 „	·32	·20	·40	·13

It appears from this table that wire rope is most efficient up to about 3 miles, beyond which electric and pneumatic transmission are most efficient.

Table 38.—TRANSMITTING POWER: *Comparative Cost of Plants per H.P. transmitted.* (Beringer.)

Maximum H.P. transmitted.	Distance of transmission.	Capital outlay per H.P.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope.
	ft.	£	£	£	£
5	300	73	40	71	6
	1,500	76	64	94	30
	3,000	79	94	204	59
	15,000	105	348	584	296
	30,000	138	594	1,060	740
	60,000	204	1,206	2,000	1,188
10	300	50	29	58	5
	1,500	53	44	70	22
	3,000	55	63	86	46
	15,000	75	214	208	225
	30,000	100	406	360	448
	60,000	150	784	662	910
50	300	39	16	30	2
	1,500	40	20	35	7
	3,000	41	30	41	14
	15,000	54	89	86	67
	30,000	67	166	143	132
	60,000	97	316	258	265
100	300	31	14	25	1
	1,500	32	20	29	4
	3,000	34	27	33	8
	15,000	44	86	65	40
	30,000	57	160	106	79
	60,000	85	302	187	158

Table 39.—TRANSMITTING POWER: *Comparative Cost per Steam Power H.P. received.* (Beringer.)

Maximum H.P. transmitted.	Distance of transmission.	Cost per H.P. received.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope.
	ft.	*d.*	*d.*	*d.*	*d.*
5	300	2·3	2·55	2·75	1·15
	1,500	2·35	2·9	3·0	1·45
	3,000	2·45	3·2	3·35	2·9
	15,000	2·9	6·6	5·3	5·5
	30,000	3·35	10·65	9·65	10·5
	60,000	5·25	19·25	16·95	23·0
10	300	2·0	2·4	2·55	1·15
	1,500	2·1	2·6	2·7	1·4
	3,000	2·15	2·85	2·9	1·75
	15,000	2·55	5·65	4·55	4·55
	30,000	3·65	7·8	6·35	8·6
	60,000	4·9	14·5	10·55	19·35

Table 39.—TRANSMITTING POWER, &c.—*continued.*

Maximum H.P. transmitted.	Distance of transmission.	Cost per H.P. received.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope.
	ft.	*d.*	*d.*	*d.*	*d.*
50	300	1·9	1·65	2·05	1·1
	1,500	1·95	1·7	2·15	1·2
	3,000	2·0	1·8	2·2	1·3
	15,000	2·3	2·95	2·9	2·55
	30,000	2·8	4·25	3·6	4·55
	60,000	4·3	7·9	5·35	11·25
100	300	1·8	1·65	2·0	1·1
	1,500	1·85	1·7	2·05	1·15
	3,000	1·95	1·8	2·1	1·25
	15,000	2·2	2·9	2·65	2·25
	30,000	2·65	4·2	3·15	3·9
	60,000	4·15	6·95	4·55	9·85

Table 40.—TRANSMITTING POWER: *Comparative Cost per Water Power H.P. received.* (Beringer.)

Maximum H.P. transmitted.	Distance transmitted.	Cost per H.P. received.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope
	ft.	*d.*	*d.*	*d.*	*d.*
5	300	·35	·29	·40	·11
	1,500	·36	·38	·47	·19
	3,000	·37	·48	·58	·30
	15,000	·45	1·40	1·28	1·26
	30,000	·52	2·53	2·43	2·53
	60,000	·85	4·85	4·50	4·92
10	300	·27	·25	·35	·09
	1,500	·28	·30	·38	·17
	3,000	·29	·37	·45	·25
	15,000	·36	·96	·89	·97
	30,000	·47	1·56	1·44	1·93
	60,000	·72	3·21	4·02	4·05
50	300	·23	·15	·22	·09
	1,500	·24	·18	·24	·11
	3,000	·26	·22	·28	·13
	15,000	·29	·46	·44	·38
	30,000	·31	·77	·65	·73
	60,000	·55	1·44	1·09	1·63
100	300	·20	·16	·22	·08
	1,500	·22	·17	·23	·10
	3,000	·23	·19	·24	·11
	15,000	·26	·43	·36	·28
	30,000	·32	·73	·48	·48
	60,000	·50	1·15	·84	1·20

Table 41.—TRANSMITTING POWER: *Hydraulic.*

Formulæ for the flow of water, in which v *is the velocity in inches per second and* s *the hydraulic inclination.* (Kutter.)

For smooth pipes ½ in. to 2½ in. diameter		$v = 107\, d^{.9} \sqrt{s}$
„ „ 2½ „ 5 „		$v = 115\, d^{.8} \sqrt{s}$
„ „ 5 „ 10 „		$v = 134\, d^{.7} \sqrt{s}$
„ „ 10 „ 72 „		$v = 166\, d^{.6} \sqrt{s}$
„ „ 6 ft. to 400 ft. „		$v = 256 \sqrt{d\, s}$
For moderately smooth pipes ½ in. to 2½ in. dia.		$v = 63\, d \sqrt{s}$
„ „ 2½ „ 5 „		$v = 68\, d^{.9} \sqrt{s}$
„ „ 5 „ 10 „		$v = 78\, d^{.8} \sqrt{s}$
„ „ 10 „ 24 „		$v = 100\, d^{.7} \sqrt{s}$
„ „ 24 „ 96 „		$v = 138\, d^{.6} \sqrt{s}$
„ „ 8 ft. to 400 ft. „		$v = 221 \sqrt{d\, s}$

Table 42.—TRANSMITTING POWER: *Electric Mining Motors.*

H.P. of Motor.	Speed.	Volts.	Amperes.	Approximate Weight.	Price of Motor.	Size of Lead-covered and Double Insulation Cable recommended.	Approximate Cost of Cable per Mile.	Price of Dynamo.
					£	B.W.G.	£	£
2	1200	200	9·5	3 cwts.	30	$\frac{7}{18}$	60	34
4	1200	200	18·5	4½ „	40	$\frac{7}{17}$	80	45
6	1200	200	27·5	6 „	50	$\frac{7}{16}$	100	57
9	1000	250	31·5	10 „	75	$\frac{19}{18}$	120	84
12	850	300	35·0	15 „	100	$\frac{19}{16}$	120	112
16	800	350	39·0	1 ton	125	$\frac{7}{14}$	150	142
20	750	400	41·5	1¼ „	150	$\frac{7}{14}$	150	170
25	700	450	46·5	2 tons	175	$\frac{19}{17}$	175	200
30	650	500	49·5	2½ „	200	$\frac{19}{17}$	175	225

Table 43.—*Transmission of Stored Power.* (Kapp.)

Source of Power.	Distance in Miles Attainable with 90 per cent. Efficiency of Transmission over—		
	Road.	Tram.	Rail.
Coal and steam engine	115	270	1,300
Corn and horse	52	170	440
Storage battery and electromotor	4	10	26

Table 44.—*Transmission Plant for 5 H.P.* (Kapp.)

Distance of Transmission in miles.	Annual Cost per H.P. delivered, if the Transmission is—		
	By Batteries.	Direct.	
		Overhead.	Underground.
	£	£	£
1	36·1	22·8	33·6
2	37·6	25·6	47·2
3	39·1	28·0	60·0
4	40·6	30·6	74·0
5	42·1	33·0	87·0

Table 45.—*Formulæ for Electric Transmission of Power.* (Kapp.)

$$\text{Volts} = H\,v\,l\,10^{-8}$$

$$\text{Kilogrammes} = \frac{H\,c\,l}{9{,}810{,}000}$$

C Total current through armature.
c Current through single armature conductor.
e_a E.M.F. in armature in volts.
τ Number of active conductors counted all round armature.
p Number of pairs of poles ($p = 1$ in a two-pole machine).
n Speed in revolutions per minute.
F Total induction in C.G.S. lines.
Z " English lines.

Electromotive force

$$\left.\begin{aligned} e_a &= F\,\tau\,\frac{n}{60}\,10^{-8} \\ e_a &= Z\,\tau\,n\,10^{-6} \end{aligned}\right\}\text{ for two pole machines.}$$

$$\left.\begin{aligned} e_a &= p\,F\,\tau\,\frac{n}{60}\,10^{-8} \\ e_a &= p\,Z\,\tau\,n\,10^{-6} \end{aligned}\right\}\text{ for multipolar machines with series wound armature.}$$

Torque

$$\left.\begin{aligned} \text{Kilogramme-metres} &= 1{\cdot}615\ F\,\tau\,C\,10^{-10} \\ \text{Foot-pounds} &= 7{\cdot}05\ Z\,\tau\,C\,10^{-6} \end{aligned}\right\}\text{ for two-pole machines.}$$

$$\left.\begin{aligned} \text{Kilogramme-metres} &= 3{\cdot}23\ F\,\tau\,c\,p\,10^{-10} \\ \text{Foot-pounds} &= 14{\cdot}10\ Z\,\tau\,c\,p\,10^{-6} \end{aligned}\right\}\text{ for multipolar machines.}$$

Table 46.—*Most Economical Current for Electric Power Transmission.* (Kapp.)

D	Distance in miles.
a	Section of conductor in sq. in.
E	Terminal volts at generator.
e	Terminal volts at motor.
HP_g	Brake horse-power required to drive generator.
HP_m	Brake horse-power obtained from motor.
c	Current in amperes.
	Efficiency of generator, 90 per cent.; efficiency of motor, 90 per cent.
g	Cost in £ per electrical horse-power output of generator.
m	Cost in £ per brake horse-power output of motor, including regulating gear.
$G = \cdot 9g\ HP_g$ ..	Cost in £ of generator.
$M = m\ HP_m$ ..	Cost in £ of motor and regulating gear.
$t = 18\cdot 2\ Da$ ..	Weight in tons of copper in line.
K	Cost in £ per ton of copper, including labour in erection.
s	Cost in £ of supports of line per mile run.
p	Cost in £ of one annual brake horse-power absorbed by generator.
q	Percentage for interest and depreciation on the whole plant.

$$\text{Capital outlay} = g\frac{Ec}{746} + m\ HP_m + Ds + \frac{1\cdot 6\ K\ D^2 c^2}{Ec - 830\ HP_m} = A.$$

$$\text{Annual cost per brake horse-power delivered} = q\frac{A}{HP_m} + p\frac{HP_g}{HP_m}.$$

$$\text{Put } B = \frac{Ep}{670} + q\frac{Eg}{746}.$$

$j = \dfrac{830}{E} HP_m$, the current which would be required if the line had no resistance,

and $\beta = j^2 \dfrac{E\ B}{1\cdot 6\ q\ K\ D^2 + E\ B}$; then the most economical current at the given voltage E is—

$$c = j\left\{1 + \sqrt{1 - \frac{\beta}{j^2}}\right\}$$

$$c = j\left\{1 + \sqrt{\frac{1\cdot 6\ q\ K\ D^2}{1\cdot 6\ q\ K\ D^2 + B\ E}}\right\}$$

For very long distances the term under the square root approaches unity, and the most economical current the value $2j$; from which it follows that under no circumstances will it be economical to lose more than half the total power in the line.

Table 47.—*Cost of Transmission of Power Plant.* (Kapp.)

Distance in Miles.	H.P. Delivered.	Speed of Machines.	Cost in £.			Total Cost.*	Cost per H.P.
			Gen.	Mot.	Line.		
						£	£
1·870	85	450	640	560	440	1,880	22·2
·280	195	500	760	680	132	1,800	9·7
·280	51	600	320	280	60	720	14·1
·375	90	550	520	480	80	1,240	13·8
·560	71	600	440	400	60	1,010	14·6
·280	40	700	260	240	20	640	16
·375	75	600	480	440	68	1,120	15
·500	87	500	520	480	100	1,260	14·5
1·560	150	600	760	720	330	2,050	13·7
·220	93	450	440	420	232	1,270	13·7
6·250	11	900	132	110	480	960	87
2·200	51	600	360	320	300	1,140	22·4
·187	60	900	240	220	18	600	10
5·000	41	750	240	200	344	1,020	24·8
3·750	220	600	1,040	960	640	2,960	13·5
·002	15	600	112	104	8	252	16·8
·250	19	700	160	160	20	390	20·5

* This includes regulating apparatus, instruments, posts, insulators, lightning arresters, erection, and supervision.

Table 48.—*Schaffhausen Electric Power Transmission Plant.* (Kapp.)

	Generators.	Twin Motor.	Small Motors.
Number of machines	2	1	2
Normal horse-power	300	380	60
Number of poles in magnet fields	6	6	2
Revolutions per minute	300	300	350
Terminal voltage	624	600	600
Normal current, amperes	330	500	81
Diameter of armature, inches	47½	42½	23¾
Length of armature core, inches	20	20¾	22½
Radial depth of armature core	8	7	4¾
Section of armature conductor, square inches	·103	·078	·0287
Number of armature conductors	316	316	540
Number of commutator segments	158	158	90
Loss in armature resistance per cent.	1·46	1·52	2·7
Induction in armature, C.G.S. measure	7,500	7,600	15,800
Shunt resistance, ohms	140	143	295
Loss in shunt excitation per cent.	1·35	1·68	—
Main turns per magnet	6	4	—
Loss in main excitation per cent.	·3	·2	—
Type of armature	Drum	Drum	Cylinder

The power is transmitted from a turbine station across the Rhine to the Schaffhausen spinning mills, a distance of about 750 yd. At

Schaffhausen Plant—continued.

the generating station are four turbines, each of 350 H.P., of which only two are at present in use, and the energy delivered at the turbine pulleys is sold to the mill owners at the rate of 2*l*. 16*s*. per H.P. per annum. From the turbine pulleys two 6-pole dynamos are driven by cotton ropes, each dynamo having an output of 330 amperes at 624 volts when running at 300 rev. per minute. These machines are over-compounded, so as to give a constant potential of 600 volts at the motor end of the line, and in ordinary working are coupled in parallel. At the receiving station is a twin motor of 380 H.P., and two other motors, each of 60 H.P. The twin motor is 6-pole, and the smaller motors 2-pole, and the power is transmitted from them to the mill shafting by cotton ropes. There are four main conductors, all overhead, each having a sectional area of ·437 sq. in., and being supported by iron towers 46 ft. high; the span across the river is 330 ft, and each of the remaining spans is 430 ft. The guaranteed commercial efficiency reckoned from the turbine pulleys is 78 per cent., the variation of speed of the motors between full and no load not more than 3 per cent., the life of a set of brushes not less than 2000 hours, and of a commutator not less than 20,000 hours. The total cost of the electrical part of the plant, including iron towers and erection, was 6800*l*.

The use of alternate current generators and motors for large transmissions has much in its favour; there are no commutators, and by having transformers at both ends of the line the working potential may be 10,000 or 25,000 volts, or even higher still, while the potential at the machines is only a few hundred volts. An ordinary alternate-current dynamo can easily be run as a motor, but, as such, it is not self-starting, and if overloaded to the extent of 50–100 per cent., may get out of step with the supply current and come to a standstill. There is another method of alternate-current transmission, known as the "three-phase current" system, which has neither of the above objections; it is a development of the Ferraris two-wire and of the Tesla three-wire systems, but with it the transmission and plant efficiencies are much greater than with the Tesla system. An objection to the Ferraris system is that the speed of the motor is not self-regulating, but may vary from zero to the synchronising speed according to the load.

TRANSMITTING POWER: *Electric Accumulators in Mines.* (Pocock.)

The use of accumulators in mines is not far off, and it will be of interest to many to see how far this reservoir of power will bear filling and drawing upon at the present time, and what the relative cost of the two electrical systems may be expected to be, not so much in first outlay as in the running expenses of the plant.

The first thing to be decided is the weight of these accumulators, and the easiest way to define this, is the weight per H.P. Salom says it takes 25 lb. of battery to give 1 H.P.-hour, and that to give 100 H.P.-hours, or 10 H.P. for 10 hours, requires 5500 lb. of battery

Electric Accumulators—continued.

or 220 elements; but 25 lb. is the net weight and 32 lb. the real total upon which we must base our calculations, so that we have a total of 7040 lb. as the weight of this battery. Then as to the room this will take upon a mine-locomotive. A mine-locomotive of 10 H.P. should not be more than 9 ft. long, and 2 ft. of this will be taken up by the bumpers, leaving 7 ft. in length for the battery. Then for a 3 ft. track it should not be more than 5 ft. wide. Allowing 1 in. all round a cell, it will be possible to set 96 of these on the floor-space of the locomotive; but we must have 14 more than this, which will make the width 68 in. The height of this cell is 8 in.; and, allowing 2 in. space above it, and 1½ in. of plank, the top of the second tier will be 19½ in. high above the floor.

If the motor is to be placed below this floor (and there is no other place for it), then the bottom of the floor will be 2·6 in. from the track; and, allowing the floor to be 3 in. thick to stand the weight, the top of this car will be 4 ft. 4½ in. above the track. Remembering that the height of the 40 H.P. motor at Lykens Valley is only 4 ft., and that the one at Erie Colliery, also 40 H.P., is 4 ft. 4 in. high, and that they are both narrower and of the same length as the proposed storage-motor, and of four times the power, there is certainly one point established against the present use of accumulators.

Table 49.—*Weight, etc., of Electric Mine-Locomotives.* (Pocock.)

Location.	Horse-power of Motor.	Weight of Locomotive. lb.	Largest Load. Tons.	Speed. Miles per hour.
Zankerode	4·5	3000	13½	6
Paulus	5 to 6	4200	..	6
Lykens	40	12,000	165	6·8
"	40	12,000	150	6·8
Shawnee	..	4500	21	5
Buckingham	..	7000	60	8
"	..	4000	30	8
Bear Run	60	18,000	150	6
Erie	40	13,500	107	6

To the weight of accumulators, 7040 lb., must be added that of motor, say 1300 lb., wheels and axles, say 1100 lb., and frame of machine, say, for strength alone, 1400 lb., giving a total weight of 10,840 lb.

From this it appears that the small German motors weigh about 700 lb. per H.P., and that the large American motors only weigh 300 lb. per H.P., whereas the accumulator-motor would weigh at least 1000 lb. per H.P. It is true that weight is necessary to traction, but it is also true that unnecessary weight will entail loss of power, and it appears that 700 lb. per H.P. is found to work satisfactorily with small motors, and that the weight per H.P.

Electric Mine Locomotives—continued.

decreases as the H.P. increases. Consequently, for a 10 H.P. motor, 1000 lb. per H.P. appears to be too high. There will be a waste of power in moving this weight, and, if we wished to operate a 40 H.P. locomotive with batteries, the number of cells would be 880, and their weight 28,160 lb. They might be divided into two batteries and towed in a tender, but even then each would weigh 14,080 lb., and this would absorb at least 500 lb. of the total pull of the motor, when running on the level, and considerably more where grades are to be overcome.

Dr. Lewis Bell has pointed out that, while a good roadbed is necessary for electrical traction by overhead wire, it is even more imperatively so when storage-batteries are used. We have found in practice that a 25 lb.-per-yard steel rail is too light for a locomotive of 13,000 lb. weight to be run upon; therefore, there is no saving to be looked for in this direction by the use of accumulators. On the contrary, when we begin to put in a roadbed heavy enough to stand the weight of a locomotive weighing, say, 23,000 lb., there are many disadvantages that the colliery-manager will be the first to see. Besides the first cost of the track, the keeping of this weight of track in good repair in a mine where the floor is for ever moving (as it is in many of our mines), would be a work of no slight expense in itself. It appears, therefore, that not much is to be expected from accumulators as a means of haulage.

However, this is one side of the question only. There is another side which should be considered, and that is the use of the accumulator-motor in collecting the cars to a point where the heavy haulage-motor can reach them. The prospect, as viewed from this point, is more encouraging. From what I have seen of the work, a motor of about 5 H.P. would do the work of 3–4 mules, and the weight would be about 5000 lb., as follows:

	lb.
Accumulators (110 cells)	3500
Motor	600
Wheels and frame	1000
Total weight	5100

This machine could be built low, so as to take up little height. It is only possible to make this form a commercial success, in my opinion, when the gangways are low and the roofs would have to be cut to gain height enough for mules to work. Then, the cost of the cutting saved by the use of the motor would counterbalance the repairs on the battery, and the extra care and expense in laying and keeping the track in order. The cost of the system may be estimated as follows—assuming the first cost of the locomotive complete to be 460*l.*, and allowing that the mine can afford to charge these cells for 8*l.* per H.P. per year, the generator and engine being already installed and doing work during the day-time,

Electric Mine Locomotives—continued.
and this sum representing fuel and interest on machinery. The attendance should not be more than 60*l*. per year, as the pump-man and night engineer can do the work:

Table 50.—*Estimate of Expense of 5 H.P. Accumulator-Motor.*

	£	s.
Interest, at 6 per cent., on 460*l*.	27	12
Repairs to battery	100	0
Repairs to motor, etc.	30	0
Cost of power, at 8*l*. per H.P.	40	0
Attendance in charging at night	60	0
Engineer, at 8*s*. per day, for 260 days	104	0
	361	12

Table 51.—*Cost of running three mules and drivers.*

Interest and depreciation (26 per cent.) on 90*l*. ..	23	10
Feed, shoeing, harness, and attention, at 1*s*. 4*d*. per day	72	5
Three drivers, for 260 days, at 8*s*. per day ..	312	0
Total	407	15
Less	361	12
Annual saving on 3 mules ..	46	3
Or, for 4 mules: total expense	543	10
Less	361	12
Annual saving on 4 mules ..	181	18

Or, about 44 per cent. on the investment, under the circumstances assumed.

The rail and track being an important item in the economy of this method, I think that perhaps the cheapest, and at the same time the best method would be to use 20–25 lb. steel rail, and, in laying the track, to place the ties first about 3 ft. apart centre to centre, and on these, and under each rail, to place a string-piece of wood $1\frac{1}{2}$ by 3 in., nailed to the ties, and spike the rails on the top, keeping the stringer-joints and the rail-joints from coinciding. The combination makes a solid track, and a very smooth-running one, and it has the advantage of not lifting easily into very uneven points; the ends of the rails do not jump as when only laid on the ties, and the track has not the spring to it which is so injurious.

The true place for accumulators at present is in lighting, and it looks as if they could be used to advantage in this connection.

Electric Accumulators—continued.

They are very heavy, it is true; but the lighting-arrangement for 8 hours' work would not be a large or very heavy affair, and could be taken to the working-place on the first car, and brought out on the last, so that it would not have to be carried by hand at all. The advantage to the operator would be material, as the men can work better in good light than in poor, and the coal would come faster and cleaner from a well-lighted place. The lighting of switches, turnouts, etc., could be easily accomplished in all parts of the mine, and the jar which would be detrimental to traction would not occur in this case. The charging could be done at night, and a clear steady light delivered during the working hours.

Table 52.—*Transmitting Capacity of Shafting.* (Webber.)

The following table gives the number of horse-power which may be safely transmitted by wrought-iron shafting, properly supported, at 100 rev. per minute:

First Movers, Carrying Main Pulley or Gear.		Second Movers, or Line Shafting, 8 ft. Spans.		Third Movers, or Short Counter Shafts, with Bearings near Pulleys.	
Diameter. in.	H.P.	Diameter. in.	H.P.	Diameter. in.	H.P.
1	1	1	2	1	3
1·25	1·95	1 1/8	2·85	1 1/16	3·59
1·50	3·37	1 1/4	3·90	1 1/8	4·27
1·75	5·36	1 3/8	5·19	1 3/16	5·02
2	8	1 1/2	6·74	1 1/4	5·85
2·25	11·39	1 5/8	8·58	1 5/16	6·78
2·50	15·62	1 3/4	10·72	1 3/8	7·79
2·75	20·80	1 7/8	13·18	1 7/16	8·91
3	27	2	16	1 1/2	10·12
3·25	34·33	2 1/8	19·19	1 9/16	11·19
3·50	42·87	2 1/4	22·78	1 5/8	12·87
3·75	52·73	2 3/8	26·79	1 11/16	14·41
4	64	2 1/2	31·24	1 3/4	16·07
4·25	76·77	2 5/8	36·17	1 13/16	17·86
4·50	91·12	2 3/4	41·60	1 7/8	19·77
4·75	107·17	2 7/8	47·53	1 15/16	21·81
5	125	3	54	2	24·00
5·25	144·70	3 1/8	60·92	2 1/16	26·32
5·50	166·37	3 1/4	68·66	2 1/8	28·78
5·75	190·11	3 3/8	76·89	2 3/16	31·40
6	216	3 1/2	85·74	2 1/4	34·17
—	—	3 5/8	95·27	2 5/16	37·09
—	—	3 3/4	105·46	2 3/8	40·18
—	—	3 7/8	116·37	2 7/16	43·44
—	—	4	128	2 1/2	46·87

For other velocities, multiply by the number of revolutions and divide by 100.

TRANSMITTING POWER: *Belt Gearing.*

The resistance of belts to slipping is independent of their breadth, consequently there is no advantage derived from increasing their dimension beyond that which is necessary to enable the belt to resist the strain. The ratio of friction to pressure for belts over wooden drums is, for leather belts, when worn ·47, when new ·5, and when over turned cast iron pulleys, ·24 and ·47. A leather belt will safely and continuously resist a strain of 350 lb. per sq. in. of section, and a section of ·2 sq. in. will transmit the equivalent of 1 H.P. at a velocity of 1000 ft. per minute over a wooden drum, and ·4 sq. in. over a turned cast iron pulley. In high speed belting the tension or the breadth of the belt should be increased in order to prevent belt from slipping. Long belts are more effective than short ones. A single belt 1 in. wide, travelling at a velocity of 1000 ft. per minute, transmits 1 H.P. A double belt 1 in. wide, travelling 700 ft. per minute, transmits 1 H.P. When a double belt is long and runs over large pulleys it may be calculated to do 1 H.P. of work at a speed of 500 ft. per minute. The upper side of the pulley should always carry the slack belt. To throw a belt on to its pulleys, when it has been laid off, it should always be laid on to the pulley that is not in motion first, and then be thrown over the edge of the moving pulley on to its face. A belt will transmit about 30 per cent. more power, with a given tension, when the grain (smooth side of the leather) is in contact with the pulley than when the flesh side is turned inward. The leather is also less liable to crack, as the structure on the flesh side is less dense, and the fibres more extensible. The adhesion of belts is greater on polished than on rough pulleys, and is about 50 per cent. greater on a leather covered pulley than on a polished iron pulley. Larger pulleys and drums may be covered with narrow strips of leather or with longer strips wound spirally. Pulley covers are manufactured in strips of the desired width, and reduced to uniform thickness by machinery. Belts should be kept soft and pliable by applying tallow occasionally, and neats-foot or liver oil, with a little rosin when they become hard and dried. Rubber belts ought always to be kept free from grease and animal oils. If they slip, moisten the inside of the belt with boiled linseed oil. Fine chalk sprinkled on over the oil will help the belt.

To Find Length of Belts.—Rule: Add the diameter of the two pulleys together, multiply by $3\frac{1}{8}$, divide the product by two, add to the quotient twice the distance between the centre of the shafts, and the product will be the required length.

To Calculate Power of Belting.—1 in. single belt moving at a velocity of 1000 ft. per minute = 1 H.P.; 1 in. double belt moving 700 ft. per minute = 1 H.P. Then H.P. of any belt equals its velocity in ft. per minute, multiplied by its width and divided by 1000 for single and by 700 for double belts.

Belt Gearing—continued.

To Calculate Speed of Drums and Pulleys.—

(*a*) The diameter of the driven being given, to find its number of revolutions. *Rule:* Multiply the diameter of the driver by the number of its revolutions, and divide the product by the diameter of the driven, the quotient will be the number of revolutions of the driven.

(*b*) The diameter and revolutions of driver being given, to find the diameter of the driven that shall make any given number of revolutions in the same time. *Rule:* Multiply the diameter of the driver by its number of revolutions and divide the product by the number of revolutions of the driven; the quotient will be the diameter.

(*c*) To ascertain the size of the driver. *Rule:* Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the diameter of the driver.

In ordering pulleys, the *exact* size of the shaft on which they are to go must be given; and the finish on the face should be flat for shifting belt, rounding for non-shifting belt.

Table 53.—*Diameter and Horse-power of Shafting.* Revolutions per minute.

Diam. of Shaft.	1	50	75	100	110	120	130	150	175	200	225	250	300	400	500	1000
in.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
1	·0099	·495	·742	·990	1·039	1·118	1·287	1·485	1·732	1·980	2·229	2·475	2·97	3·960	4·990	9·9
1¼	0175	·875	1·3125	1·75	1·925	2·10	2·275	2·625	3·062	3·5	3·937	4·375	5·25	7·0	8·75	17·5
1½	·03	1·50	2·25	3·0	3·30	3·60	3·90	4·50	5·25	6·0	6·75	7·50	9·0	12·0	15·0	30·0
1¾	·045	2·25	3·375	4·5	4·95	5·4	5·85	6·75	7·875	9·0	10·125	11·25	13·5	18·0	22·5	45·0
2	·07	3·5	5·15	7·0	7·7	8·4	9·1	10·5	12·5	14·0	15·75	17·5	21·0	28·0	35·0	70·0
2¼	·1	5·0	7·5	10·0	11·0	12·0	13·0	15·0	17·5	20·0	22·5	25·0	30·0	40·0	50·0	100·0
2½	·130	6·5	9·75	13·0	14·3	15·6	16·9	19·5	22·75	26·0	29·25	32·5	39·0	52·0	65·0	130·0
2¾	·165	7·5	11·25	15·0	16·5	18·0	19·5	22·5	26·25	30·0	33·75	37·5	45·0	60·0	75·0	150·0
3	·225	11·25	16·875	22·5	24·75	27·0	29·25	33·75	39·375	45·0	50·6	56·2	67·5	90·0	112·5	225·0
3¼	·275	13·75	21·62	27·5	30·25	32·0	34·75	41·25	47·75	55·0	61·875	68·75	82·5	110·0	137·5	275·0
3½	·33	16·5	24·75	33·0	36·3	40·20	42·9	49·5	57·75	66·0	74·25	82·5	99·0	132·0	165·0	330·0
3¾	·412	20·6	30·9	41·2	45·32	49·44	53·56	61·8	71·10	82·4	92·7	103·0	123·6	164·3	206·0	412·0
4	·5	25·0	37·5	50·0	55·0	60·0	65·0	75·0	87·5	100·0	112·5	125·0	150·0	200·0	250·0	500·0
4¼	·6	30·0	45·6	60·0	66·0	72·0	78·0	90·0	105·0	120·0	135·0	150·0	180·0	240·0	300·0	600·0
4½	·725	35·25	54·27	72·5	79·75	86·0	94·25	108·70	126·87	145·0	163·0	180·0	217·0	280·0	350·0	725·0
4¾	·85	42·5	63·75	85·0	93·5	102·0	110·0	127·0	143·0	170·0	191·0	212·0	255·0	340·0	425·0	850·0
5	1·0	50·0	75·0	100·0	110·0	120·0	130·0	150·0	175·0	200·0	225·0	250·0	300·0	400·0	500·0	1000·0
5½	1·325	66·0	99·0	132·0	145·0	159·0	172·0	198·0	232·0	265·0	298·0	331·0	397·0	530·0	662·0	1324·0
6	1·725	86·0	139·0	172·0	189·0	207·0	221·0	258·0	301·0	345·0	388·0	431·0	517·0	690·0	862·0	1724·0
6½	2·175	108·0	163·0	217·0	239·0	261·0	282·0	326·0	380·0	435·0	489·0	543·0	652·0	870·0	1087·0	2174·0
7	2·7	135·0	202·0	270·0	297·0	324·0	351·0	405·0	472·0	540·0	607·0	675·0	810·0	1080·0	1350·0	2700·0

This table is calculated for general shafting, transmitting power by belt pulleys. For shafting carrying heavy weights or transmitting power by gears, diameter should be increased accordingly.

Table 54.—TRANSMITTING POWER: *Horse-power and Breadth of Leather Belts.* (Nystrom.)

B = breadth of belt in in.
HP = horse-power transmitted by the belt.
V = velocity in ft. per second of the belt.
d = diameter in in. } of the smallest pulley.
n = revolutions per minute } of the smallest pulley.
F = motive force in lb. transmitted by the belt.
Z = half angle of contact of belt on the small pulley.
S = safe working strength in lb. per in. of width of belt, which for oak-tanned leather ¼ in. thick, cemented and riveted joints, can be taken at 100 lb. and less in proportion for weaker belts.

$$\mathrm{HP} = \frac{d\,n\,\mathrm{F}}{126050} = \frac{60\,\mathrm{B\,V}}{1000} \text{ for single thickness} \quad (1)$$

$$\mathrm{HP} = \frac{\mathrm{B}\,d\,n\,\mathrm{Z\,S}}{15000000} \quad (2)$$

$$\mathrm{HP} = \frac{\mathrm{B\,V\,Z\,S}}{130000} \quad (3)$$

$$\mathrm{B} = \frac{15000000\ \mathrm{HP}}{d\,n\,\mathrm{Z\,S}} \quad (4)$$

$$\mathrm{B} = \frac{\mathrm{T} + t}{2\,\mathrm{S}} \quad (5)$$

$$\mathrm{F} = \frac{126050\ \mathrm{HP}}{d\,n} = \frac{550\ \mathrm{HP}}{\mathrm{V}} \quad (6)$$

Ex. A leather belt is to transmit HP = 75 horse-power over a pulley $d = 36$ in. diameter, making $n = 80$ revolutions per minute; angle of contact Z = 85°, and the safe working strength S = 100 lb. per in. of width. Required the width of the belt.

$$\text{Width } b = \frac{15000000 \times 75}{36 \times 80 \times 85 \times 100} = 46 \text{ in. nearly.}$$

Table 55.—TRANSMITTING POWER: *Breadth of Belts in Inches for different Motive Forces and Angles of Contact.* (Nystrom.)

Motive Force.	Whole Angle of Contact 2 Z.									
	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°
F lb.	B in.	B in.	B in.	B in.	B in	B in.	B in.	B in.	B in.	B in.
10	0·424	0·372	0·331	0·300	0·275	0·254	0·238	0·223	0·211	0·200
20	0·847	0·743	0·662	0·599	0·549	0·509	0·475	0·446	0·421	0·400
30	1·271	1·115	0·993	0·898	0·824	0·763	0·713	0·670	0·632	0·600
40	1·695	1·487	1·324	1·198	1·099	1·018	0·950	0·893	0·842	0·800
50	2·119	1·859	1·655	1·497	1·374	1·272	1·183	1·116	1·053	1·000
60	2·543	2·230	1·987	1·796	1·648	1·526	1·425	1·339	1·263	1·200
70	2·966	2·602	2·318	2·095	1·923	1·780	1·663	1·562	1·474	1·400
80	3·390	2·974	2·648	2·396	2·195	2·036	1·900	1·786	1·684	1·600
90	3·813	3·345	2·930	2·695	2·472	2·290	2·138	2·009	1·895	1·800
100	4·237	3·717	3·311	2·994	2·747	2·544	2·375	2·233	2·105	2·000
120	5·034	4·460	3·974	3·592	3·296	3·053	2·850	2·678	2·526	2·400
140	5 932	5·204	4·636	4·190	3·846	3·560	3·326	3·124	2·948	2·800
160	6·780	5·948	5·296	4·792	4·396	4·072	3·800	3·572	3·368	3·200
180	7·626	6·690	5·960	5·390	4·944	4·580	4·276	4·018	3·790	3·600
200	8·474	7·434	6·622	5·988	5·494	5·088	4·750	4·464	4·210	4·000
220	9·321	8·177	7·284	6·586	6·043	5·596	5·225	4·910	4·631	4·400
240	10·17	8·920	7·948	7·184	6·592	6·104	5·700	5·356	5·052	4·800
260	11·02	9·663	8·610	7·783	7·141	6·613	6·175	5·800	5·473	5·200
280	11·86	10·41	9·273	8·380	7·692	7·120	6·652	6·248	5·896	5·600
300	12·71	11·15	9·933	8·982	8·241	7·632	7·125	6·696	6·315	6·000
320	13·56	11·90	10·59	9·584	8·692	8·144	7·600	7·144	6·736	6·400
340	14·41	12·64	11·21	10·18	9·241	8·652	8·075	7·590	7·157	6·800
360	15·25	13·38	11·92	10·78	9·948	9·160	8·552	8·036	7·580	7·200
380	16·10	14·12	12·58	11·38	10·53	9·669	9·027	8·482	8·001	7·600
400	16·95	14·87	13·24	11·98	10·99	10·180	9·500	8·928	8·420	8·000

Table 55—*continued.*

Motive Force.	Whole Angle of Contact 2 Z.									
	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°
F lb.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.
420	17·80	15·61	13·90	12·58	11·54	10·69	9·97	9·34	8·84	8·40
440	18·64	16·35	14·57	13·17	12·09	11·19	10·45	9·82	9·26	8·80
460	19·49	17·09	15·23	13·77	12·64	11·70	10·93	10·27	9·68	9·20
480	20·34	16·84	15·90	14·37	13·13	12·21	11·40	10·71	10·10	9·60
500	21·19	18·59	16·55	14·97	13·74	12·72	11·88	11·16	10·53	10·00
600	25·42	22·30	19·87	17·96	16·48	15·26	14·25	13·39	12·63	12·00
700	29·66	26·02	23·18	20·95	19·23	17·80	16·63	15·62	14·74	14·00
800	33·90	29·74	26·48	23·96	21·98	20·36	19·00	17·86	16·84	16·00
900	38·13	33·45	29·80	26·95	24·72	22·90	21·38	20·09	18·95	18·00
1000	42·37	37·17	33·11	29·94	27·47	25·44	23·75	22·32	21·05	20·00
1100	46·61	40·89	36·42	32·93	29·22	27·98	26·12	24·55	23·15	22·00
1200	50·84	44·60	39·74	35·92	32·96	30·52	28·50	26·78	25·26	24·00
1300	55·08	48·32	40·05	38·91	35·71	33·06	30·87	29·01	27·36	26·00
1400	59·32	52·04	46·36	41·90	38·56	35·60	33·26	31·24	29·48	28·00
1500	63·56	55·76	49·67	44·89	41·31	38·14	36·63	33·47	31·58	30·00
1600	67·80	59·48	52·96	47·92	43·96	40·72	38·00	35·72	33·68	32·00
1700	72·04	63·20	56·27	50·91	46·71	43·26	40·38	37·95	35·78	34·00
1800	76·26	66·90	59·60	53·90	49·44	45·80	42·76	40·18	37·90	36·00
1900	80·50	70·62	62·91	56·89	52·19	48·34	45·14	42·41	40·01	38·00
2000	84·74	74·34	66·22	59·88	54·94	50·88	47·50	44·64	42·10	40·00
2100	88·98	78·06	69·53	62·87	57·69	53·42	49·88	46·87	44·21	42·00
2200	93·21	81·77	72·84	65·86	60·43	55·96	52·25	49·10	46·31	44·00
2300	97·45	85·49	76·15	68·85	63·18	58·50	54·63	51·33	48·42	46·00
2400	101·70	89·20	79·48	71·84	65·92	61·04	57·00	53·56	50·52	48·00
2500	105·50	92·95	82·75	74·85	68·70	63·50	59·40	55·80	52·65	50·00

Table 55—*continued.*

Motive Force.	Whole Angle of Contact 2 Z.									
	160°	170°	180°	190°	200°	210°	220°	230°	240°	250°
F lb.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.
10	0·190	0·182	0·175	0·163	0·162	0·157	0·152	0·148	0·144	0·140
20	0·381	0·365	0·350	0·337	0·325	0·314	0·304	0·295	0·287	0·280
30	0·571	0·547	0·525	0·505	0·487	0·472	0·457	0·442	0·431	0·420
40	0·762	0·730	0·700	0·673	0·649	0·629	0·609	0·591	0·574	0·560
50	0·952	0·912	0·875	0·841	0·811	0·786	0·761	0·738	0·718	0·700
60	1·143	1·094	1·051	1·010	0·974	0·943	0·913	0·884	0·862	0·840
70	1·333	1·276	1·226	1·178	1·136	1·100	1·065	1·032	1·005	0·980
80	1·524	1·459	1·401	1·346	1·298	1·258	1·218	1·182	1·149	1·120
90	1·714	1·642	1·576	1·515	1·461	1·415	1·370	1·326	1 292	1·260
100	1·905	1·824	1·751	1·683	1·623	1·572	1·522	1·477	1·436	1·400
120	2·286	2·188	2·102	2·020	1·948	1·886	1·826	1·768	1·723	1·680
140	2·667	2·553	2·452	2·357	2·273	2·200	2·130	2·063	2·010	1·960
160	3·048	2·918	2·802	2·692	2·596	2·516	2·436	2·264	2·298	2·240
180	3·429	3·283	3·152	3·029	2·921	2·830	2·740	2·659	2·585	2·520
200	3·810	3·648	3·502	3·366	3·246	3·144	3·044	2·954	2·872	2·800
220	4·191	4·013	3·852	3·703	3·571	3·458	3·348	3·249	3·159	3·080
240	4·572	4·376	4·204	4·040	3·896	3·772	3·652	3·536	3·446	3·260
260	4·953	4·741	4·554	4·377	4·221	4·086	3·956	3·831	3·733	3·540
280	5·334	5·105	4·904	4·714	4·546	4·400	4·260	4·126	4·020	3·820
300	5·715	5·472	5·253	5·049	4·869	4·716	4·566	4·421	4·308	4·200
320	6·096	5·836	5·604	5·384	5·192	5·032	4·872	4·528	4·596	4·480
340	6·477	6·201	5·954	5·720	5·516	5·346	5·176	4·823	4·883	4·760
360	6·858	6·564	6·306	6·060	5·944	5·658	5·478	5·304	5·169	5·040
380	7·239	6·929	6·656	6·397	6·269	5·972	5·782	5·599	5·456	5·320
400	7·620	7·296	7·004	6·732	6·732	6·233	6·088	5·908	5·744	5·600

Table 55—*continued.*

Motive Force.	Whole Angle of Contact 2 Z.									
	160°	170°	180°	190°	200°	210°	220°	230°	240°	250°
F lb.	B in.	B in.	B in.	B in.	B in.	B in	B in.	B in.	B in.	B in.
420	8·001	7·661	7·354	7·068	6·816	6·602	6·492	6·203	6·031	5·88
440	8·382	8·026	7·704	7·406	7·142	6·916	6·696	6·498	6·318	6·16
460	8·763	8·391	8·054	7·743	7·466	7·230	7·000	6·793	6·605	6·44
480	9·144	8·752	8·408	8·080	7·792	7·544	7·304	7·072	6·892	6·52
500	9·525	9·120	8·755	8·415	8·115	7·860	7·610	7·385	7·180	7·00
600	11·43	10·94	10·51	10·10	9·738	9·432	9·132	8·842	8·616	8·40
700	13·33	12·76	12·26	11·78	11·36	11·00	10·65	10·32	10·04	9·80
800	15·24	14·59	14·01	13·46	12·98	12·58	12·18	11·82	11·49	11·20
900	17·14	16·42	15·76	15·15	14·61	14·15	13·70	13·26	12·92	12·60
1000	19·05	18·24	17·51	16·83	16·23	15·72	15·22	14·77	14·36	14·00
1100	20·95	20·06	19·26	18·51	17·85	17·29	16·74	16·25	15·80	15·40
1200	22·86	21·88	21·02	20·20	19·48	18·86	18·26	17·68	17·23	16·80
1300	24·76	23·70	22·77	21·88	21·10	20·43	19·78	19·16	18·67	18·20
					[illegible]		21			
					24		22			
			[illegible]		25		14·3			
			29·77		27		15·8			
			31·52		2		17·4			
			33·27		3		18·9			
			35·02		3	4	10·4			
	10		36·77		3	0	1·9	3		
	11		38·52		3	5	3·4	3		
	13		40·27		3	1	5·0	3		
	5		42·04		3	7	6·5	3		
	7		43·79		[illegible]	2	8·0	3		

WEIGHTS AND MEASURES.

Table 56.—*Miscellaneous.*

Basalt	187 lb. per cub. ft.	
Clay	100 „ „	28 cub. ft. = 1 ton.
Clay slate	180 „ „	
Coal, anthracite	50–55 „ „	
„ „ broken, 1 cub. ft. = 1·75 cub. ft.		
„ bituminous ..	40–50 lb. per cub. ft.	
„ „ ..	70–78 „ heaped bushel.	
„ „ Cannel	50 „ cub. ft.	
„ „ Cumberland	53 „ „	
„ „ Lancashire		44 cub. ft. = 1 ton.
„ „ Newcastle		45 „ „
„ „ R.N. allowance		48 „ „
„ „ Scotch		43 „ „
„ „ Welsh		43 „ „
Gravel, coarse		23 „ „
„ free from cement and containing no heavy boulders, wet	90–100 lb. per cub. ft.	
„ ditto do. dry	80– 90 „ „	
„ boulders not over 6 in. diameter, wet	95–105 „ „	
„ ditto do. do. dry	85– 95 „ „	
„ 18 cub. ft. in bank = 27 cub. ft. dry = 1 ton.		
Limestone, solid	170 lb. per cub. ft.	
„ broken	96 „ „	
Loam, wet, loose	72–80 „ „	
„ „ packed	90–100 „ „	
„ dry, loose	66–68 „ „	
„ „ packed	85–95 „ „	
Loose dirt, about 400 cub. in. to a miners' pan.		
Quartz, solid	165 „ „	
„ broken	94 „ „	
Sand, dry	88–90 „ „	
„ wet	118–120 „ „	
Shale	162 „ „	
„ decomposed	100 „ „	
Traprock	170 „ „	
Wood, 4 ft. × 4 ft. × 8 ft. = 128 cub. ft. = 1 cord.		
„ charcoal, 18 lb. per cub. ft., 124½ cub. ft. = 1 ton.		

Table 57.—WEIGHTS AND MEASURES: *Minerals*. (Haswell.)

—	Sp. gr.	Lb. per cub. ft.	—	Sp. gr.	Lb. per cub. ft.
Alabaster, white	2730	170·625	Earth, loose	1500	93·75
" yellow	2699	168·687	" moist sand	2050	128·125
Alum	1714	107·125	" mould, fresh	2050	128·125
Amber	1078	67·375	" rammed	1600	100
Asbestos, starry	3073	192·062	" rough sand	1920	120
Asphalte	2250	140·625	" with gravel	2020	126·25
Barytes, sulphate	4000	250	" potters'	1900	118·75
	4865	304·062	" light vegetable	1400	87·5
Basalt	2740	171·25	Emery	4000	250
	2864	179	Felspar	2600	162·5
Bitumen, red	1160	72·3	Flint, black	2582	161·375
" brown	830	51·7	" white	2594	162·125
Borax	1714	107·125	Fluorine	1320	82·5
Brick	1367	85·437	Fuel, Warlich's	1150	71·875
	1900	118·75	" Lignite	1300	81·25
" pressed	2100	150	Gneiss, common	2700	158·75
" fire	2201	137·562	Granite, Egyptian red	2654	165·875
" work in cement	1800	112·5	" Patapsco	2640	165
" " " mortar	1600	100	" Quincy	2652	165·75
	2000	125	" Scotch	2625	164·062
Carbon	3500	218·75	" Susquehanna	2704	169
Cement, Portland	1300	81·25	" " grey	2800	175
" Roman	1560	97·25	Graphite	2200	137·5
Chalk	1520	95	Gravel, common	1749	100
	2784	174	Grindstone	2143	133·937
Clay	1930	120	Gypsum, opaque	2168	135·5
" with gravel	2480	155	Hone, white, razor	2876	179·75
Coal, Anthracite	1350	84·375	Hornblende	3540	221·25
	1436	89·75	Iodine	4940	—
	1640	102·5	Lava, Vesuvius	1710	106·875
" Borneo	1290	80·625		2810	175·625
" Cannel	1238	77·375	Lias	1350	146·875
	1318	82·575	Lime, quick	804	50·25
" Caking	1277	79·812	" hydraulic	2745	171·562
" Cherry	1276	79·75	Limestone, white	3156	197·25
" Chili	1290	80·625	" green	3180	198·75
" Derbyshire	1292	80·75	Magnesia, carbonate	2400	150
" Lancaster	1273	79·562	Magnetic ore	5094	317·6
" Maryland	1355	84·687	Marble, Adelaide	2715	169·687
" Newcastle	1270	79·375	" African	2708	169·25
" Rive de Gier	1300	81·25	" Biscayan, black	2695	168·437
" Scotch	1259	78·687	" Carrara	2716	169·75
	1300	81·25	" common	2686	167·875
" Splint	1302	81·375	" Egyptian	2668	166·75
" Wales, mean	1315	82·187	" French	2649	165·562
Coke	1000	62·5	" Italian, white	2708	169·25
" Nat'l, Va.	746	46·64	" Parian	2838	177·375
Concrete, in cement	2200	137·5	" Silesian	2730	170·625
" mean	2000	125	" Vermont, white	2650	165·57
Earth, common soil, dry	1216	76	Marl, mean	1750	109·375
			" tough	2340	146·25

Table 57—*continued.*

—	Sp. gr.	Lb. per cub. ft.
Masonry, rubble ..	2050	128·125
„ Granite ..	2640	165
„ Limestone ..	2640	165
„ Sandstone ..	2160	135
„ Brick	2240	140
„ „ rough-work	1600	100
Mica	2800	175
Millstone	2484	155·25
„ Quartz ..	1260	78·75
Mortar	1384 1750	86·5 109·375
Mud	1630	101·875
„ wet and fluid ..	1782	112
„ „ „ pressed	1920	120
Nitre	1900	118·75
Paving-stone	2416	151
Peat, Irish, light ..	278	17·375
„ „ dense ..	562	35·125
„ „ very dense	675	42·187
„ black ..	1058 1329	66·125 83·062
Phosphorus	1770	110·625
Plaster of Paris..	1176 3400	73·5 212·5
„ „ dry ..	1400	87·5
Porcelain, China ..	2300	143·75
Porphyry, red	2765	172·812
Pumice	915	57·187
Quartz	2660	166 25
Red lead	8940	558·75
Rock, crystal	2735	170·937
Rotten-stone	1981	123·812
Salt, common	2130	133·125
„ rock	2200	137·5
Saltpetre	2090	130·625
Sand, coarse	1800	112·5
„ common	1670	104·375
„ damp and loose	1392	87
„ dried „ „	1560	97·5
„ dry	1420	88·75
Sand, mortar, Ft. Richmond	1659	103·66
„ „ Brooklyn	1716	107·25
„ silicious	1701	106·33
Sandstone, mean ..	2200	137·5
„ Sydney ..	2237	139·81
Schorl	3170	198·125
Scoria, volcanic.. ..	830	51·875
Shale	2600	162·5
Slate	2672 2900	167 181·25
„ purple	2784	174
Smalt	2440	152·5
Soapstone	2730	170·625
Spar, calcareous ..	2735	170·937
„ feld, blue ..	2693	168·312
„ „ green ..	2704	169
„ fluor	3400	212·5
Specular ore	5251	328·187
Stalactite	2415	150·937
Stone, Bath	1961	122
„ Blue Hill ..	2640	165
„ Bluestone (basalt)	2625	164·062
„ Breakneck, N.Y.	2704	169
„ Bristol	2510	156·875
„ Caen, Normandy	2076	129·75
„ common.. ..	2520	157·5
„ Craigleith ..	2316	144·75
„ Kentish rag. ..	2651	165·687
„ Kip s Bay, N.Y.	2759	172
„ Norfolk (Parliament House)	2304	144
„ Portland ..	2368	148
„ Staten Island, N.Y.	2976	186
„ Sullivan Co. ..	2688	168
Sulphur, native ..	2033	127·062
Terra cotta	1952	122
Tile	1815	113·437
Trap	2720	170

Table 58.—WEIGHTS AND MEASURES: *Precious Stones.*

	Sp. gr.
Agate	2595
Amethyst	2620
Carnelian	2613
Chrysolite	2782
Diamond, Oriental	3521
„ Brazilian	3444
„ pure ..	3550
Emerald	2750
Emerald, aqua marine	2730
Garnet	4189
„ black	3750
Jasper	2600
Jet	1300
Lapis lazuli	2960
Malachite	4020
Onyx	2700
Opal	2090
Pearl, Oriental ..	2650
Ruby	3980
Sapphire..	3994
Topaz	3500
Tourmaline	2970
Turquoise	2750

Table 59.—WEIGHTS AND MEASURES: *Metals.* (Haswell.)

—	Sp. gr.	Lb. per cub. in.	—	Sp. gr.	Lb. per cub. in.
Aluminium, cast	2560	·0926	Iron, wrought, pure	8140	·2938
„ wrought	2670	·0906	„ ordinary mean	7744	·2801
„ bronze	7700	·2785	Lead, cast	11352	·4106
Antimony	6712	·2488	„ rolled	11388	·4119
Arsenic	5763	·2084	Lithium	590	·0213
Barium	470	·017	Magnesium	1750	·0633
Bismuth	9823	·3553	Manganese	8000	·2894
Boron	2000	·0723	Mercury − 40°	15632	·5661
Brass—			„ + 32°	13598	·4918
Sheet, cop 75, zinc 25	8450	·3056	„ + 60°	13569	·4908
Yellow „ 66, „ 34	8300	·2997	„ +212°	13370	·4836
Muntz „ 60, „ 40	8200	·2966	Molybdenum	8600	·3111
Plate	8380	·3026	Nickel	8800	·3183
Cast	8100	·2930	„ cast	8279	·2994
Wire	8214	·2972	Niobium	6000	·217
Bromine	3000	·1085	Osmium	10000	·3613
Bronze, gun metal	8750	·3165	Palladium	11350	·4105
„ ordinary mean	8217	·2972	Platinum, hammered	20337	·7356
„ cop. 84, tin 16	8832	·3194	„ native	16000	·5787
„ „ 81, „ 19	8700	·2929	„ rolled	22069	·7982
„ small bells,			Potassium, 59°	865	·0313
cop. 35, tin 65	8060	·291	Red lead	8940	·324
„ „ 21, „ 74	7390	·2668	Rhodium	10650	·3852
Cadmium	8650	·3129	Rubidium	1520	·055
Calcium	1580	·057	Ruthenium	8600	·3111
Chromium	5900	·2134	Selenium	4500	·1627
Cinnabar	8098	·2929	Silver, pure, cast	10474	·3788
Cobalt	8600	·3111	„ „ hammered	10511	·3802
Columbium	6000	·217	Sodium	970	·0351
Copper, cast	8788	·3179	Steel, minimum	7700	·2785
„ plates	8698	·3146	„ maximum	7900	·2857
„ wire and bolts	8880	·3212	„ plates, mean	7806	·2823
„ ordinary mean	8880	·3212	„ soft	7833	·2833
Gold, pure, cast	19258	·6965	„ tempered and		
„ hammered	19361	·7003	hardened	7818	·2828
„ 22 carats fine	17486	·6325	„ wire	7847	·2838
„ 20 „ „	15709	·5682	„ blistered	7823	·283
Iridium	18680	·6756	„ crucible	7842	·2836
„ hammered	23000	·8319	„ cast	7848	·2839
Iron, cast	7308	·264	„ Bessemer	7852	·284
„ minimum	6900	·2491	„ ordinary mean	7834	·2916
„ maximum	7500	·2707	Strontium	2540	·0918
„ ordinary mean	7207	·2607	Tellurium	6110	·221
„ mean, Eng.	7217	·2609	Thallium	11850	·4286
„ cast, hot blast	7065	·2555	Tin, Cornish, hamm'r'd	7390	·2673
„ „ cold „	7218	·2611	„ „ pure	7291	·2637
„ wrought bars	7788	·2817	Titanium	5300	·1917
„ „ wire	7774	·2811	Tungsten	17000	·6149
„ „ roll'd pl't's	7704	·2787	Uranium	18330	·6629
„ „ average	7698	·2779	Wolfram	7119	·2575
„ „ Eng. rails	7540	·2722	Zinc, cast	6861	·2482
„ „ Lowmoor	7808	·2819	„ rolled	7191	·26

Table 60.—WEIGHTS AND MEASURES: *Metals* (Molesworth).

Wrought Iron.

Cubic inches × ·28 = lb. avoirdupois.
,, × 100 = qr.
,, × 400 = cwt.
Thickness of plates in inches × 40 = lb. per sq. ft.
,, ,, eighths × 5 = ,, ,,
,, ,, tenths × 4 = ,, ,,
Sectional area in inches × 3·34 = lb. per lin. ft.
,, ,, eighths × ·052 = ,, ,,
,, ,, inches × 10 = lb. per lin. yd.
Lb. per lineal yard × ·7857 = tons per mile run.
Diameter of round iron in inches squared × 2·64 = lb. per foot run.

Various Metals.

Multipliers to convert the weights as found above into the weights of other metals.

Weight of wrought iron	×	·92	=	weight of	zinc.
,, ,, ,,	×	·93	=	,,	cast iron.
,, ,, ,,	×	·94	=	,,	tin.
,, ,, ,,	×	1·02	=	,,	steel.
,, ,, ,,	×	1·09	=	,,	brass.
,, ,, ,,	×	1·15	=	,,	copper.
,, ,, ,,	×	1·47	=	,,	lead.
Cub. in. ,, ,,	×	·252	=	lb. of	zinc.
,, ,, ,,	×	·26	=	,,	cast iron.
,, ,, ,,	×	·262	=	,,	tin.
,, ,, ,,	×	·288	=	,,	steel.
,, ,, ,,	×	·3	=	,,	brass.
,, ,, ,,	×	·32	=	,,	copper.
,, ,, ,,	×	·41	=	,,	lead.

A bar of wrought iron 1 × 1 and 1 yd. long weighs 10 lb.

Rule for Weight of Pipes.

D = Outside diameter of pipe in inches.
d = Inside diameter.
w = Weight of a lineal foot of pipe in lb.
$w = k\,(D^2 - d^2)$.
k = 2·45 for cast iron.
= 2·64 for wrought iron.
= 2·82 for brass.
= 3·03 for copper.
= 3·86 for lead.

Table 61.—*Mexican Mining Weights.*

1 grano	=		·7716 gr.
12 granos	= 1 tomin	=	9·2592 „
6 tomines	= 1 ochava	=	·12685 oz.
8 ochavas	= 1 onza	=	1·0148 „
8 onzas	= 1 marco	=	8·1184 „

The *marco* is the unit for weighing bullion.

Mexicans value an ore at so many *marcos* of silver per *carga*. instead of oz. per ton.

The *carga* = 12 *arrobas* = 304·332 lb.

To reduce *onzas* per *carga* to oz. per ton, multiply by 6·078; and to convert oz. per ton to *onzas* per *carga*, multiply by ·165.

The *monton* in Zacatecas	= 20 quintals	=	2000 lb.
„ „ Guanajato	=		3200 „
„ „ some places	=		3000 „
„ „ others	= 4 cargas	=	1200 „

Table 62.—*Surveying Measures.*

Circle, diameter	×3·1416	= circumference.
„ „	× ·8862	= side of an equal square.
„ „	× ·7071	= side of an inscribed square.
„ area = diameter²	× ·7854.	
„ circumference	× ·31831	= diameter.
Circular inches	× 183,346	= 1 sq. ft.
Sphere, diameter³	× ·5236	= solidity.
„ diameter	× ·806	= dimensions of equal cube.
„ „	× ·6667	= length of equal cylinder.
Cylindrical inches	× ·0004546	= cub. ft.
„ „	× ·002832	= gal.
„ „	2200	= 1 cub. ft.
„ feet	× ·02909	= cub. yd.
Square, side	×1·128	= diameter of an equal circle.
„ root of acre	×1·12837	= diameter of an equal circle.
„ inches	× ·00695	= sq. ft.
„ feet	× ·0000229	= acres.
„ yards	× ·0002066	= acres.
Cubic inches	× ·00058	= cub. ft.
„ feet	× ·03704	= cub. yd.
„ „	× ·6232	= gal.
Lineal feet	×1·51515	= links.
„ „	× ·00019	= miles.
„ yards	×4·54545	= links.
„ „	× ·000568	= miles.
„ links	× ·66	= ft.
„ „	× ·22	= yd.
„ chains	× ·0125	= miles.

Table 62—*continued.*

Lineal miles	× 5,280	= ft.
" "	× 1,760	= yd.
" "	× 80	= chains.
Acres	×43,560	= sq. ft.
"	× 4,840	= sq. yd.

Area of circle = diameter² × ·7854.
" parallelogram = base × height.
" trapezium : divide into two triangles and find area of each.
" trapezoid = height × ½ the sum of the parallel sides.
" triangle = base × ½ height.
Latitude (northing or southing) = cos. of angle of bearing × distance.
Departure (easting or westing) = sin. of angle of bearing × distance.
Level, difference of = sin. of angle of inclination × hypothenuse.
Horizontal measurement = cos. of angle of inclination × hypothenuse.
Inclination, rate of (ratio of base to perpendicular) = cotan. of angle of inclination.
Slope, rate of (ratio of hypothenuse to perpendicular) = cosec. of angle of inclination.

Table 63.—*Areas of Circles.*

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
in.	sq. in.	in.	sq. in.	in.	sq. in.	in.	sq. in.	in.	sq. in.
⅛	·012	7½	44·17	20	314·16	32½	829·5	45	1590·4
¼	·049	8	50·26	20½	330·06	33	855·3	45½	1625·9
⅜	·110	8½	56·74	21	346·36	33½	881·4	46	1661·9
½	·196	9	63·61	21½	363·05	34	907·9	46½	1698·2
¾	·441	9½	70·88	22	380·13	34½	934·8	47	1734·9
1	·785	10	78·54	22½	397·60	35	962·1	47½	1772·0
1⅛	·994	10½	86·59	23	415·47	35½	989·8	48	1808·5
1¼	1·227	11	95·03	23½	433·73	36	1017·8	48½	1847·4
1½	1·767	11½	103·87	24	452·39	36½	1046·3	49	1885·7
1¾	2·405	12	113·10	24½	471·43	37	1075·2	49½	1924·4
2	3·141	12½	122·71	25	490·8	37½	1104·4	50	1963·5
2¼	3·976	13	132·73	25½	510·7	38	1134·1	50½	2002·9
2½	4·908	13½	143·13	26	530·9	38½	1164·1	51	2042·8
2¾	5·939	14	153·94	26½	551·5	39	1 94·6	51½	2083·0
3	7·06	14½	165·13	27	572·5	39½	1225·4	52	2123·7
3¼	8·29	15	176·71	27½	593·9	40	1256·6	52½	2164·7
3½	9·62	15½	188·69	28	615·7	40½	1288·2	53	2206·1
3¾	11·04	16	201·06	28½	637·9	41	1320·2	53½	2248·0
4	12·56	16½	213·82	29	660·5	41½	1352·6	54	2290·2
4½	15·90	17	226·98	29½	683·4	42	1385·4	54½	2332·8
5	19·63	17½	240·52	30	706·8	42½	1418·6	55	2375·8
5½	23·75	18	254·46	30½	730·6	43	1452·2	55½	2419·2
6	28·27	18½	268·80	31	754·7	43½	1486·1	56	2463·0
6½	33·18	19	283·53	31½	779·3	44	1520·5	56½	2507·1
7	38·48	19½	298·64	32	804·2	44½	1555·2	57	2551·7

PROSPECTING.

These notes refer chiefly to gold, but embrace other metals and such gems as are found in alluvial formations.

Streams.—As a rule, those streams which cross the laminations of reefs at right angles, or nearly so, are the richest. Gold is found very rarely in those parts of streams where the current has been the strongest, but generally in the lee or under the shelter of projecting points of rocks, where beaches are usually formed; and wherever such beaches exist there also may gold be looked for with fair chances of success. But the straight courses of streams, especially when they cross the laminations of the bed-rock at right angles, are also often very rich in gold. As a rule, the gold in streams is deposited in the crevices of the bed-rock, which must be laid as dry as possible, and picked up to such depths as the sand descends between its laminations. Very rarely is the gold found mixed up in the gravel lying in the beds of streams.

Terraces.—Terrace prospecting requires more experience, labour, perseverance, and, consequently, more time than creek prospecting. Terraces are those shelf-like excavations upon the hill-slopes flanking valleys and lakes, and are the remains of old river-beds; so that the rules above laid down for the deposition of gold in streams apply also to terraces. Sometimes a ridge of rock divides a terrace from the newer river-channel, but this is not always the case. The first thing to do in prospecting a terrace is to discover its inlet, and next to find its outlet. This found, the "wash" should be carefully examined for the prevailing indications of gold peculiar to the locality in which the terrace occurs, and also for gold. The whole width of the channel of the terrace from the edge to the high or back reef must be carefully prospected, both along the bed-rock and also through the whole depth of the "wash," from the surface down; for the terrace "wash," being often deposited at different geological times, not unfrequently contains gold in layers one above the other. These terraces are very numerous in New Zealand; and a study of the river systems of the present, as well as of the preceding geological ages, will assist the prospector greatly in his choice of a likely spot where to set in. There is a general fall in the country lying along the main directions of the present streams, which indicates the leading course upon which all alluvial gold has been deposited, the consideration of which is often a reliable guide to the level of terraces which are covered up completely by landslips, or in which either the inlet or the outlet is hid from view. In New Zealand large fortunes lie buried in many locations thus hid,

Terraces—continued.
require a great amount of prospecting to unearth; so that prospectors have an extensive field before them in this direction.

Table-lands.—The gold found at these elevations belongs to a different geological age from the gold generally obtained in New Zealand. This opinion is supported by the nature of the wash in which the table-land gold is found, nothing like it being met with on lower levels. In looking for new deposits of this description, the prospector should not be deterred by the elevation of any table-land, for gold in really astonishing quantities has been got at Mount Criffel, upwards of 4000 ft., and at Mount Pisa, nearly 6000 ft. above sea-level. Nor need much attention be paid to the "wash" in these places: and, indeed, its total absence does not necessarily imply the absence of gold. As a rule, the sinking upon these table-lands is shallow and easy, and often the gold is distributed evenly throughout the body of the "wash," or else occurs in layers one above the other, as well as upon the bed-rock. So far as discovered, these deposits occur upon mountain-tops bordering the principal Otago goldfields, rather than upon those in their midst, the gold being found deposited in a somewhat erratic manner.

Beach-workings.—Beach-workings may receive a passing notice, as the ocean beaches of the Middle Island have contributed considerable quantities of gold to the total yield of the colony. And the same may be said of dredging the larger rivers—an enterprise often highly remunerative. Both descriptions of gold-raising are capable of much extension and improvement. (Miller.)

Vein Outcrops.—Whilst working up the stream, attention must be paid to the banks on each side, especially where they show a section of the rocks, so that no outcropping vein may be overlooked. Should a quartzose or pyritous vein be discovered, specimens must be broken down for examination.

As all alluvial gold is the result of the breaking up of auriferous veins, an effort should always be made to trace the former to its source. Many valuable reefs have been found in this way. The occurrence of "float," or stray pieces of quartz, if of a promising appearance, should be taken as a guide also. Obviously, some judgment is necessary in estimating the best direction for search, and in determining the drainage area to which the float belongs. Sometimes there may be much difficulty in locating the reef, owing to disturbances or to accumulation of detritus hiding the nature of the subjacent rock. A knowledge of the neighbouring reefs and their gold is of great assistance. Where the gold specks and pebbles are much worn, they may represent a former riverine deposit, or its remains, scattered far from its previous resting-place. Where the gold is heavy and the rock fragments are angular, the reef cannot be very far distant. Occasionally there may be a distinct feature in all the veins in a district, such as a peculiar band of defined colour, and the recurrence of this indicator should

Veins—continued.
then stimulate search for the accompanying reef. Coarse alluvial gold is not always incompatible with fine reef gold as a source, because the reef gold may be so fine in general as to lend itself to very wide distribution when once liberated, while the rarer coarse grains would not be transported far.

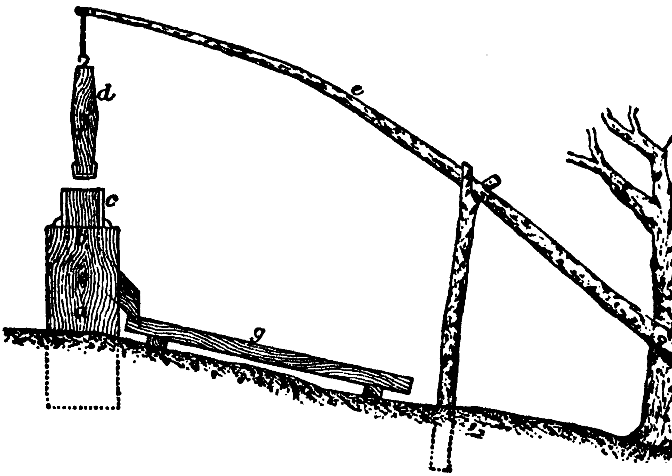
Much intelligent prospecting for auriferous reefs is done by "loaming," as a preliminary to cutting experimental trenches or sinking trial shafts. Loaming, long practised in searching for tin in Cornwall, consists in washing surface prospects from the bases and slopes of the ranges, until specks of gold or specimens are found to be obtainable with tolerable frequency within certain limits. The prospector then proceeds to trace the gold up-hill to its source, narrowing the limits of his work, as by slow and patient search he approaches the reef whence the gold has been derived. When he finds that he can obtain surface prospects of gold up to a certain point or line, but no farther, he then proceeds by means of trenching, &c., to search for the reef. As may be imagined, the work is one requiring patience, energy, and insensibility to fatigue, together with good memory for locality, as the prospector frequently has to work along a steep and scrubby mountain side, selecting his prospects, numbering them, and placing them in his "loam-bag," noting the localities, and then conveying his samples many hundred feet down the ranges to water. If he be fortunate in obtaining prospects of gold, he has to find his way back to the spots the samples were taken from, so as to continue his up-hill search, and trace the gold to its matrix. In many new discoveries made by means of the above system there was no surface indication whatever of the existence of a reef; nothing visible to the eye that would have led one passing over the ground to believe that it was there, the soil and débris completely concealing its outcrop, until by means of "loaming," the prospector was enabled so nearly to ascertain its position as to expose it in a trench of not many feet in length.

Prospecting Stamps.—In order to obtain proper samples of the vein-stuff for testing, it is necessary to reduce it to a fine state of subdivision, such as is ordinarily accomplished in the stamp battery.

A primitive yet efficient apparatus for this purpose, and such as may be erected by the prospector himself without the aid of much engineering skill, is shown in Fig. 9, and goes by the name of a "dolly." On the end of a solid log *a*, fixed in the ground and standing about 4 ft. high, is cut a square hole *b*, about 6 in. across, in which are firmly fitted wrought-iron bars about ½ in. apart, ½ in. thick and 3 in. deep, made thinner beneath, so that whatever enters above will fall through. A wooden box *c* is placed round this to keep the ore from jumping away. A square block of wood *d*, about 3 or 4 ft. long, shod with wrought iron, and small enough at the lower end to work in the box, forms the stamper. It is hung on the end of a long pole *e*, the spring of which keeps it on

Stamps—continued.
the swing without too much labour. It is worked by laying hold with the hands of a wooden pin *f* on each side of the stamper, and pulling it down, its own rebound and the spring of the pole taking

Fig. 9.



Dolly, or Prospecting Stamp.

it up again. The iron bars might be replaced by an old stamp die. The gold is caught on the table *g*, which is covered with amalgamated copper plate or blanket.

Table 64.—PROSPECTING: *Boring.*

Cost of some trial borings for ironstone in the Barrow district, made with the aid of a steam winch and free-falling tool:—

Depth of Hole.	Diameter of Hole.	Cost per yd.	Cost of Labour alone.	Time occupied.
yd.	in.	*s.* *d.*	£ *s.* *d.*	weeks
126	6 to 2	7 10½	49 10 0	15
124*	"	9 7	59 8 0	18
50	"	9 10¾	24 15 0	7½
63	"	9 5	29 14 0	9
76½	"	6 0½	23 2 0	7
88	"	8 3	36 6 0	11
48	"	11 0	26 8 0	8

* The strata passed through in this hole were as follows, proceeding from the surface downwards:—45 ft. pinder, 75 ft. red sand, 3 ft. white sand, 30 ft. red sand mixed with clay, 150 ft red sand, 30 ft. red and white sand, 6 ft white sand, 6 ft. shale, 4 ft ore, 6 ft. clay, 1 ft. ore, 2 ft. stone, 9 ft. ore, 2 ft. black shale, 3 ft. stone —total, 372 ft.

Table 65.—Approximate cost per set of boring tools, including rigger, rope, and ordinary shear legs, and windlass for depths of 300 ft. and upwards:—

	£		£
To bore 30 ft.	20	To bore 250 ft.	75
" 50 "	36	" 300 "	120
" 100 "	45	" 500 "	155
" 150 "	58	" 800 to 1000 ft...	195
" 200 "	70		

TOOLS.

TOOLS: *Picks.*

Holing pick, S. Wales: head straight, length 18 in.; helve, 33½ in. long; weight, 3½ lb.
Cutting pick, S. Wales: head straight, length 17 in.; helve, 20½ in. long; weight, 2 lb. 14 oz.
Bottom pick, S. Wales: head, 21¼ in. long; helve, 30½ in. long; weight, 3 lb. 3 oz.
Stone pick: head, 24 in. long; helve, 30½ in. long; weight, 9 lb. 5 oz.
Holing pick, N. Wales: head, 18 in. long; helve, 28 in. long; weight, 2 lb. 10 oz.
Heading pick, N. Wales: head, 16¼ in. long; helve, 27½ in. long; weight, 3 lb.
Driving pick: head, 17¼ in. long; helve, 27½ in. long; weight, 3 lb. 10 oz.
Coal pick, N. England: head, 17½ in. long; helve, 32 in. long; weight, 4 lb. 5 oz.
Coal pick, N. England: head, 18 in. long; helve, 32 in. long, angle 155°; weight, 4 lb. 5 oz.
Stone pick, N. England: head, 19¼–23 in. long; helve, 30 in. long; weight 7–8 lb.
Poll pick, Cornwall: pick end 12½ in. long, poll end 3 in. long, eye 2·2 in. long, width over eye 3·1 in., width of poll end 1·2 in., width of pick end 1·1 in., thickness of poll end 1·2 in., thickness of pick end 1·1 in.: helve, 26 in. long, set at 85°; weight, 8½ lb.
Slitter pick: head, 15·7 in. long; handle, 29 in. long; weight, 3 lb. 10 oz.
Drifting pick, California: weight, 3½–4 lb.
Poll pick, California: head, 16½ in. long; weight, 5 lb.

Helves, 1*s.* 6*d.* each. Heads, 8*d.* to 9*d.* per lb.

TOOLS: *Shovels.*

Gravel shovel: plate, 10 in. wide, mouth pointing; handle, 30 in. long, set at angle of 150°. Cost (10-12 in. wide), 25–35*s.* a doz.; steel, 60–70*s.*
Frying-pan filling shovel: plate nearly circular, 14 in. wide, 16 in. long; handle, 24 in. long, set at 142°; weight, 7 lb. 14 oz. Cost, 35–48*s.* a doz.
Round-mouthed filling shovel: plate 16 in. wide, 15 in. long; handle, 23 in. long, set at 147°; weight, 7 lb. 14 oz. Cost, 35–48*s.* a doz.; steel, 45–60*s.*
Sinking shovel: pointed plate, 11½ in. by 14 in.; handle, 23 in. long.

TOOLS: *Wedges.*

Coal wedge, S. Wales: length, $13\frac{1}{4}$ in.; central section, breadth $1\frac{7}{8}$ in., thickness $\frac{7}{8}$ in.; striking face, breadth $1\frac{1}{8}$ in., thickness 1 in.; weight 3 lb. 14 oz.

Coal wedge, N. Wales: length $11\frac{1}{2}$ in.; greatest section, breadth $1\frac{3}{4}$ in., thickness $\frac{7}{8}$ in.; weight 3 lb. 9 oz.

Coal wedge, N. England: length 12 in. greatest section.

TOOLS: *Hammers.*

Sledges.—Eye generally oval. Weight of head 5–10 lb., most commonly 7 lb. Length of helve 20–30 in., usually 24 in. for blasting, 28 in. for wedge-driving. For coal wedging, the head is generally 12 in. long and $2\frac{1}{4}$ in. max. diam., tapering to $1\frac{1}{2}$ in.

South Wales blasting sledge: head, $8\frac{3}{4}$ in. long, helve 27 in.; total weight 7 lb. North Wales ditto: head $7\frac{3}{4}$ in. long, helve 22 in.; weight $6\frac{1}{2}$ lb. North of England sledge: head 5 in. long, helve $24\frac{1}{2}$ in.; weight under 5 lb.

Hand hammers usually have a head weighing about 3 lb., and a helve 10 in. long.

TOOLS: *Drills.*

The edge of the drill may be straight, as in the flat chisel for deep drilling, or slightly curved. The straight edge cuts its way somewhat more freely than the curved, but it is weaker at the corners than the curved, a circumstance which renders it less suitable for very hard rock. It is also slightly more difficult to forge. The width of the bit varies, according to the width required, from 1 to $2\frac{1}{2}$ in. The stock is octagonal in section, and is made in lengths varying from 20 to 42 in. The shorter the stock, the more effectively does it transmit the blow, and therefore it is made as short as possible: for this reason several lengths are employed in drilling a blast-hole, the shortest being used at the commencement of the hole, a longer one to continue the depth, and a still longer one, sometimes, to complete it. To ensure the longer drills working freely in the hole, the width of the bit should be very slightly reduced in each length. The diameter of the stock is less than the width of the bit; this difference may be greater in coal drills than in rock or "stone" drills; a common difference in the latter is $\frac{3}{8}$ in. for the smaller sizes, and $\frac{1}{2}$–$\frac{3}{4}$ in. for the longer. The following proportions may be taken as the average adopted:—

Width of the Bit.	Diameter of the Stock.	Width of the Bit.	Diameter of the Stock.
1 n.	$\frac{5}{8}$ in.	$1\frac{3}{4}$ in.	$1\frac{1}{8}$ in.
$1\frac{1}{8}$ „	$\frac{3}{4}$ „	2 „	$1\frac{3}{8}$ „
$1\frac{1}{4}$ „	$\frac{7}{8}$ „	$2\frac{1}{4}$ „	$1\frac{1}{2}$ „
	1 „	$2\frac{1}{2}$ „	$1\frac{5}{8}$ „

The striking face of the drill should be flat. The diameter of the face is less than that of the stock in all but the smallest sizes,

Drills—continued.

the difference being made by drawing in the striking end. The amount of reduction is greater for the larger diameters, that of the striking face being rarely more than $\frac{7}{8}$ in.

TOOLS: *Hand-drilling Gears.*

A set of single coal-blasting gear will include a drill, 22 in. long, with cutting edge straight and $1\frac{1}{2}$ in. wide, and weight $2\frac{1}{2}$ lb.; another drill, 42 in. long, with straight cutting edge $1\frac{7}{16}$ in. wide, weight 4 lb. 10 oz.; the hammer weighs 2 lb. 14 oz.; length of head $4\frac{1}{2}$ in., and that of handle $7\frac{3}{4}$ in. A single-hand stone set includes shorter drill, 22 in. long, cutting edge strongly curved, and $1\frac{1}{2}$ in. wide, and weight 3 lb. 10 oz.; longer drill, 36 in. long, cutting edge $1\frac{7}{16}$ in. wide, and curved as in the shorter drill, and weight 6 lb. 5 oz.; hammer weighs 3 lb. 6 oz.; length of head 5 in., and that of handle 10 in. A double-hand stone set comprises first or shortest drill, 18 in. long, $1\frac{3}{4}$ in. wide on the cutting edge, and weighs $4\frac{1}{4}$ lb.; second drill, 27 in. long, $1\frac{11}{16}$ in. wide on the cutting edge, and weighs 6 lb.; third, or longest drill, 40 in. long, $1\frac{5}{8}$ in. wide on the cutting edge, and weighs $9\frac{1}{4}$ lb.; the cutting edges of all these drills are strongly curved. Sledge weighs about 5 lb.

DRILLING.

Churn-drilling.—A churn-driller will drill, in ordinary hard rock, 8–12 ft. 2-in. holes of 2·5 ft. depth per day, and at a cost of 6–9*d.* per ft., on a basis of ordinary labour at 4*s.* per day, drillers receiving 10*s.*

One man can bore, with a bit 1 in. diameter, 50–100 in. per day of 10 hours in granite, or 300–400 in. per day in limestone.

Tamping.—Two strikers and a holder can bore, with a bit 2 in. diameter, 10 ft. a day in rock of medium hardness.

Composition for waterproof charger or fuse consists by weight of pitch 8 parts, beeswax and tallow each 1 part. (Haswell.)

DRILLING: *Percussive and Rotary compared.*

In Table 64 is a statement of the work done each week in a three months' trial at North Skelton mines of percussive and rotary drills, to compare the capabilities of the two systems.

The work done by the percussive drill is represented by the *smaller* figures, and the work done by the rotary drill by the *larger* ones. When the trial commenced, the men working the rotary drill were strange to the mode of working the North Skelton stone, and did not therefore get on at all well for the first few weeks.

The yield for a set of 15 or 16 holes, put in in a wide place, varies from 22 to 34 wagons of stone. The yield for the same number of holes in a narrow place varies from 13 to 26 wagons of stone. Each wagon carries 30 cwt.; and if the figures showing the percentage of wide and narrow places drilled by each machine are noted, it will be seen that a greater percentage of narrow places have been drilled by the rotary drill than by the percussive, which (as compared with working the larger quantity from wide places) reduces the yield of stone per hole, and increases the cost of powder per ton.

If the results obtained during the first four weeks of the trial are carefully compared with those obtained during the last four weeks, the figures will, in these respects, speak for themselves. Turning to the cost of repairs during this trial, the percussive drill cost over 6*l.*, whilst the rotary was under 5*s.*; in fact, the difference between the value of the wiping hay used for cleaning the holes out in the case of the percussive and that needed by the rotary, would more than cover all the repairs required by the latter. There is a wide difference to the men between the working of these two classes of drills. In the percussive class, there is twice as much hard work required from the men as in the rotary, and in

Table 66.

Week ending.	Number of Places Drilled.	Percentage of Wide Places.	Percentage of Narrow Places.	Number of Holes Drilled.	Number of ft. and in. Drilled.		Stone got.		Shifts Worked this Week.		Average Number of Holes Drilled per Shift.	Average Length of Holes.		Average Stone got per Hole.		Average ft. and in. Drilled per Shift.		Average Time occupied in Moving Machine from place to place, in Minutes.	Excess in Quantity obtained over Percussive Drill.		Excess in Number of Holes Drilled over Percussive Drill.	Excess in ft. and in. Drilled over Percussive Drill.	
					ft.	in.	tons	cwt.	8 hrs.	6 hrs.		ft.	in.	tons	cwt.	ft.	in.		tons	cwt.		ft.	in.
1882.																							
Nov. 11	18	67·23	27·77	263	1032	8	417	17	5	1	43·8	..	..	..	..	..	..	19·00	..	..	..	..	..
"	23	39·13	60·87	321	1245	8	409	13	5	1	53·5	3	10	1	5	207	7	15·88	..	..	58	213	0
Nov. 18	..	..	..	245	..	..	..	..	5	1	40·6	..	..	..	..	..	..	..	..	..	..	..	..
"	27	40·73	59·27	344	1385	1	642	0	5	1	57·3	4	0⅓	..	..	230	10	12·33	..	..	..	..	..
Nov. 25	16	56·25	43·75	239	958	9	535	12	4	1	47·8	4	0	2	4½	191	9	19·21	..	..	..	..	..
"	25	40·00	60·00	307	1239	8	624	12	4	1	61·40	4	0½	2	0	247	11	12·00	89	0	68	280	7
Dec. 2	17	75·00	25·00	246	968	7	497	5	4	1	49·00	3	11	2	0	193	8	25·33	..	..	..	..	..
"	21	50·00	50·00	342	1333	7	624	18	4	1	68·40	3	11	1	14	266	8	12·76	127	13	96	365	0
Dec. 9	16	61·00	39·00	251	983	9	580	14	4	1	50·20	3	10	2	6	196	9	25·87	..	..	..	..	..
"	24	52·00	48·00	369	1488	9	729	6	4	1	73·80	4	0	1	19	297	9	10·09	148	12	118	505	0
Dec. 16	17	49·00	51·00	264	1014	3	566	15	4	1	52·80	3	10	2	3	202	10	24·25	..	..	..	..	..
"	25	53·00	47·00	372	1498	2	808	6	4	1	74·40	4	0	2	3	299	7	11·66	241	11	108	483	0
Dec. 23	21	66·00	34·00	303	1174	6	797	9	5	1	50·50	3	10½	2	12	195	9	25·83	..	..	..	..	..
"	29	39·60	60·40	467	1887	6	1066	4	5	1	77·80	4	0½	2	5	314	7	10·26	268	15	164	713	0
Dec. 30.	17	75·00	25·00	255	1003	5	583	6	4	1	51·00	3	7	2	5	200	8	25·56	..	..	..	..	..
"	23	59·00	41·00	353	1450	1	883	1	4	1	70·60	4	1⅓	2	10	290	0	15·90	299	15	98	446	8
1883.																							
Jan. 6	17	77·50	22·50	280	1089	4	678	7	5	1	46·66	3	10⅓	2	8	181	6	..	..	..	..	..	..
"	23	47·00	53·00	390	1576	3	835	11	4	1	78·00	4	0	2	2¾	315	3	13·40	157	4	110	486	9
Jan. 13	20	86·00	14·00	332	1311	4	772	1	5	1	56·33	3	11	2	6	218	6	18·83	..	..	..	..	..
"	29	51·00	49·00	522	2110	6	1116	11	5	1	87·00	4	0½	2	2¾	351	9	13·04	344	10	190	799	2
Jan. 20	20	70·00	30·00	299	1175	5	703	18	5	1	50·00	3	11	2	7	195	11	21·36	..	..	..	..	..
"	30	52·00	48·00	501	2051	7	1049	13	5	1	83·50	4	1	2	1¾	341	11	14·03	345	15	202	876	2
Jan. 27	20	60·00	40·00	313	1220	10	802	10	5	1	52·18	3	11	2	11	203	5	22·22	..	..	..	..	..
"	30	53·00	47·00	518	2135	1	1186	0	5	1	86·30	4	1	2	5¾	355	10	12·80	383	10	205	914	3

Percussive and Rotary—continued.
point of comfort there is no comparison, the machinery in the rotary case doing all the work, and the men are kept quite dry; but in attending to the percussive, they are working very wet during the whole shift, and have to do much more laborious work in the fixing of the drill in each place, as well as during its general working. The water needed for drilling with the percussive drills has to be led out of the places going to the dip, and in all the places the state of the roads is made very disagreeable and objectionable for the men and horses travelling upon them. In the use of the percussive drills, a second costly main of pipes, with all necessary connections and cocks for conveying the water under a heavy pressure into every place, has to be provided and kept in order, involving double cost in both pipes and skilled labour.

Since the date of this competitive trial, further improvements have been added to the rotary drill, by which a 4-ft. hole can be put in with 1000 revolutions less of the engines, and the holes cleaned of the small drillings, thus saving a considerable amount of skilled labour, reducing the consumption of the compressed air and the wear and tear on the drilling machine by 71 per cent.

Both the machines here referred to have been continued at work at North Skelton every day, and (working two shifts) the rotary is now daily averaging 324 tons of stone, whilst the quantity from the percussive is not much more than one-third of this.

At the St. Andreasberg silver mines in the Harz, rock drills worked by compressed air have recently been introduced. The air compressor is placed underground, and is driven by a Girard turbine. The special point of interest in connection with this installation is the regulator, which consists of an air reservoir hewn in the solid rock. By the employment of power drills, it is found that in driving levels there is a saving in cost of 58 2 per cent., whilst 4·04 times as much work is done as that accomplished by manual labour. The cost of stoping by hand was 16*s.* as compared with 8*s.* 6*d.* by machine per cub. metre of ore won. In the case of shaft sinking, the cost with machine, inclusive of explosives, was 4*l.* per running metre, as compared with 7*l.* 10*s.* with manual labour.

Electric Mining Drills.

The transmission of power by electricity offers special advantages in the case of movable machines such as drills. This is mainly due to the fact that the power is conveyed by means of small, flexible, stationary wires or cables, which are capable of almost infinite extension, which may be buried underground, hung on the sides or roof, coiled on a drum, built at any angle, or moved from place to place, without in any way interfering with the working of the machinery; nor are the machines themselves less easily managed than the cables which transmit the power to them.

Probably no firm has done more to render electric mining

Electric Drills—continued.
machinery a practical working success than W. T. Goolden and Co., of London, and the following examples are therefore chosen from among their many mining machines to show the advances made in this direction. Goolden's drilling machines are of three classes:

(1) Rotary borers for coal or comparatively soft shale or stone.
(2) Light percussion drills for small holes in soft material.
(3) Powerful percussion drills for larger holes in hard rocks.

Class (1) is suitable for drilling shot-holes in coal and similar material, and in fact is to replace the hand-borers now frequently used. In this machine the small electric motor is mounted on the base of the machine which forms the trolley on which it is moved from place to place. It is of the usual "Goolden" mining type, all parts being completely inclosed in dirt-, damp-, and gas-tight cases, so that it can be used if required in presence of explosive mixtures of gases, without any fear of a spark causing an explosion. This motor drives a vertical shaft, which in turn drives the drill. The vertical shaft has a feather-way cut in it thoughout its length, so that the drill motion can be raised or lowered and fixed at any desired height on a tubular column provided for this purpose. By means of a simple arrangement of the gearing, the drill may be set to bore in any direction, that is at any inclination either to the horizontal or vertical planes, so that it may be said to be perfectly universal. It is further fitted with a variable feed motion, so that by the adjustment of a screw the rate of feed may be varied while the machine is working to any desired extent, thus allowing the machine to be worked all the time at its full power without fear of straining any part. The whole of the gearing is completely inclosed in dirt-tight cases to protect it from wear or damage from falling stone or *debris*, and in every way the machine is designed to meet the rough usage of ordinary mining practice. In using the machine, it may be either lifted from its carriage and allowed to stand on the base of the column, being clamped against the roof or timbers by means of a screw at the top of the column, or it may be left on the trolley and simply clamped in position as it stands, according to circumstances. The cable for use with this machine is a small "twin" or "concentric," one which may be rolled on a drum or coil or simply pulled after the machine as it is moved from place to place.

Class (2) is a small 1 to 2 H.P. percussion drill giving 100 to 200 blows per minute, and suitable for drilling holes up to 1 in. diam. in moderately hard stone. In this machine, for ease of transport, the motor and drill are made quite separate. The motor is an ordinary "Goolden" mining motor, and is mounted on a small trolley so that it can be easily moved, and is quite complete in itself, with all the necessary appliances for starting and stopping. The drill is also distinct, and much resembles some of the well

Electric Drills—continued.

known hand-power percussion drills; it is light but strong, portable but substantial, and well calculated to stand rough handling by inexperienced men. It is provided with an efficient automatic feed motion, so that it follows its work with little attention, and is readily set to drill in any direction or at any height. The power is conveyed from the motor to the drill, first through a pair of strong spur gear, in which the pinion is made of a composition of vulcanised fibre and iron, to make it run silently, and then by means of a length of flexible shafting to the drill. By this means the drill may, within wide limits, be set at any distance from or at any angle to the motor, without in any way interfering with the working of the machinery.

Class (3) is a large 5-10 H.P. reciprocating drill for drilling holes up to 2½ in. diam. in the hardest rocks, and is capable of giving 600-1000 blows per minute. This drill consists of a strong iron cylinder, resembling the cylinder of an air drill, in which are inclosed all the electrical and reciprocating parts. This cylinder is mounted on the usual sliding carriage fitted with a screw feed-motion. The drill is essentially simple in construction, and as it contains no moving electrical parts or connections, is entirely free from the objections sometimes met with in this class of machinery arising from the delicate nature of these contacts. In fact as the only moving part consists of the piston and piston-rod, and as there is no valve gear, there is less to get out of order than in the ordinary steam drill, while on account of the greater number of blows obtainable, more work can be done with this drill than with any other form of machine. The drill is mounted on a variety of forms of carriages or pillars to suit different classes of work, and is eminently suited for all classes of quarrying and mining use, while at the same time, on account of the small size of concentric cable required for transmitting power to it, it can be very readily moved from part to part of a mine as required.

Rock Drilling Plant.

The following information concerning the well-known patent Adelaide Rock-drills, has been obligingly contributed by the sole manufacturers, Commans & Co., 52, Gracechurch Street, London, E.C.

Table 67.—*Cost of Drills.*

Size	2½ in.	3 in.	3¼ in.	3½ in.	4 in. diam. of cylinder.
Price	36*l.*	40*l.*	44*l.*	47*l.*	56*l.*

Table 68.—*Cost of Accessories.*

	£	s.	d.
Stretcher bar and steel clamp	8	12	0
Tripod and weights	13	15	0
50 ft. length of hose with brass fittings complete	7	8	0
Finished steel tools, best quality, in assorted lengths and sizes, per cwt.	4	10	0
1 set of swages for sharpening tools	1	10	0

Tunnelling carriage, complete, for 4 drills 100*l.*
" " " 2 " 80*l.*

$2\frac{1}{2}$ in. and 3 in. diameter drills are best suited for ordinary quarry work where tripods are employed.

$3\frac{1}{4}$ in. and $3\frac{1}{2}$ in. diameter drills are usually used for mine purposes.

4 in. diameter drills for heavy tunnelling work, to bore holes of large diameter.

A complete mining plant (e.g. 6 drills) would consist of the following items, viz.:—

6 $3\frac{1}{2}$-in. drills, complete.
6 stretcher bars with steel clamps.
6 50-ft. lengths of covered hose with all necessary brass connections.
6 sets of best finished steel tools, in assorted lengths and sizes.
1 set of swages for sharpening tools.
1 complement of spare wearing parts.
1 18-in. direct-acting air compressor, with steam cylinder complete.
1 air-receiver, fitted with safety valve, blow-off cock, &c.
1 30 H.P. nom. boiler, complete, with donkey pump.
Connections between boiler and steam cylinders and between air cylinder and receiver.
Wrought iron air piping for conveying the compressed air to the machines.

A complete plant as above, for 6 *drills*, 3 in. or $3\frac{1}{2}$ in., would cost approximately 1300*l.* to 1400*l.*

A complete plant as above for 4 *drills*, 3 in. or $3\frac{1}{2}$ in., would cost approximately 800*l.* to 900*l.*

A small plant of say 2 3-in. drills, with 10-in. air compressor and 8 to 10 H.P. boiler would cost about 500*l.* to 600*l.*

Useful Notes on Drilling.

Supplied by Commans & Co., 52, Gracechurch Street, London.

The amount of air *at receiver pressure* required per drill per minute when working at normal speed is about:—

Size of Drill	$2\frac{1}{2}$ in.	3 in.	$3\frac{1}{4}$ in.	$3\frac{1}{2}$ in.	4 in.
Cubic ft.	8·5	12	14	16·5	21·5

For the purpose of calculating the size of compressor, it is, however, well to assume a somewhat larger amount of air per drill than

Useful Notes—continued.

given above, as often, owing to loss due to clearance, heat and leakage, the actual amount of air discharged from an ordinary compressor with poppet valves is 25 per cent. less than the theoretical amount.

Safe figures are:—

Size of Drill	$2\frac{1}{2}$ in.	3 in.	$3\frac{1}{4}$ in.	$3\frac{1}{2}$ in.	4 in.
Cubic ft.	10	15	17	20	25

With the best compressors, the loss of efficiency ought not to be more than 10 per cent. It is false economy to employ too small a compressor. Where a number of drills have to be driven, an allowance might be made, which could not be done in the case of a compressor to drive only two machines.

An effective air pressure of 50–75 lb. per sq. in. is usually employed for working drills. The lower pressures are used for drills employed on soft rock, and for machines which do not work expansively, using the full air pressure throughout the stroke. There is no economy in working with air at too low a pressure. The only limit to the pressure is the point when the tool gets too quickly blunted; the cost of the men to run the drill is a considerably greater item than that of compressing the air.

The air should be drawn from outside the engine room, and from as cool a place as possible.

When air is compressed to more than one or two atmospheres, the temperature rises rapidly, necessitating the cylinder being water jacketed. Injection of water into the cylinder, although it cools the air more rapidly, is not to be recommended, as it soon rusts the walls of the cylinder, permits only of a slow speed of piston, and produces moist air, which often causes a freezing-up of the exhaust ports of the drills. The cooling not only effects a saving in power required for compressing, but prevents decomposition of the oil, and permits proper lubrication by keeping the cylinder and glands cool. The piston speed of ordinary compressors usually varies from 250 ft. to 400 ft. per minute, according to the size of the compressor.

A good fly wheel should be employed, more especially in direct acting compressors, to ensure steady running, and to equalise the difference between the steam pressure and air resistance.

Rule.—Assuming the temperature to remain constant, and that compression is carried on isothermally, the absolute pressures (the total pressures above a vacuum) at any two points of the stroke are, according to Boyle's or Marriotte's Law, inversely proportional to the volumes at these points, so that if

P = the original pressure.
P^1 = „ new „
V = „ original volume.
V^1 = „ new „

$$P^1 : P = V : V^1.$$

Useful Notes—continued.

Ex. 1.—What vol. V^1 will 100 cub. ft. of atmospheric air (which at the sea level averages about 15 lb. per sq. in.) occupy, when compressed to 60 lb. or 4 atmospheres effective pressure (5 atmospheres absolute)?

$$V^1 = \frac{P \times V}{P^1}$$

$$= \frac{15 \times 100}{60 + 15} = 20 \text{ cub. ft.},$$

or $\frac{1}{5}$ of the original volume. So that approximately the volume of compressed air is equal to the original volume divided by the number of atmospheres (absolute) to which it has been compressed.

Ex. 2.—Required the size of compressor to supply air at 60 lb. effective pressure to work two 3-in. drills.

Air required per minute:—

$15 \times 2 = 30$ cub. ft. at 60 lb.,

or, $30 \times 5 = 150$ „ of free air at atmospheric pressure would be required per minute to work both drills simultaneously.

Taking the piston speed at 300 ft. per minute:—

$$\text{Area of cylinder} \times 300 = 150$$

$$\text{„ \quad „} \quad = \frac{150}{300} = 72 \text{ sq. in.},$$

which represents a cylinder diameter of $9\frac{5}{8}$ in., to which the nearest sized compressor would be 10 in. diameter.

A smaller plant than a 10-in. compressor and two drills is very seldom employed, and would not be economical.

Ex. 3.—Required the size of compressor to supply air at 60 lb. effective pressure to work six $3\frac{1}{2}$-in. drills.

Air required per minute:—

$20 \times 6 = 120$ cub. ft. at 60 lb. pressure,

or, $120 \times 5 = 600$ „ of free air at atmospheric pressure.

Assuming a piston speed of 350 ft. per minute:—

$$\text{Area of cylinder} \times 350 = 600$$

$$\text{„ \quad „} \quad = \frac{600}{350} \text{ sq. ft.} = 247 \text{ sq. in.},$$

which represents a cylinder of $17\frac{3}{4}$ in. diameter, the nearest sized compressor to which would be an 18-in. It would be possible to drive the 6 drills with a 16-in. compressor running a little faster, and taking into consideration that seldom more than 5 drills would

Useful Notes—continued.
be working at one time; on the other hand it would be more economical, and better in the long run, to employ an 18-in. compressor.

Compressors for Mountainous Districts.—As the density of the atmosphere decreases with the height above the sea level, allowance must be made for this when calculating a compressor plant to work at a high altitude. Taking the efficiency at the sea-level to be 100, the decrease in efficiency is approximately 3 per cent. for every 1000 ft. above the sea level.

Air Receivers.—These are inserted between the compressing engine and the machines to be driven, in order to keep as far as possible a steady working pressure, and allow the air to flow through the mains with a uniform velocity.

If the air has to be carried a very long distance, it is advantageous to employ two receivers, one close to the compressor, the other near the point where the power is being taken off. By this means a steady flow of air through the pipes is secured, and the friction is thereby considerably reduced.

No hard and fast rule can be given for the size of receivers; the larger they are within reason the better. For a single cylinder compressor the receiver should, for example, be larger than for a compressor of 2 or more cylinders. An allowance of not less than 10 cub. ft. per drill should be made. It will suffice if the volume of the receiver has a capacity of about double the volume of air discharged from the compressor.

Air Mains.—Care should be taken when designing a plant to make the mains of ample size, so as not to throttle the air, and where possible to avoid angles and bends.

Wrought or cast iron flanged pipes are best for carrying the air into the mine; ordinary steam piping can be used for the distribution of the air underground.

The loss of pressure is proportional to the length of the pipe and the square of the velocity.

A fair velocity to assume is 25-30 ft. per second, so that for example the size of main for an 18-in. compressor delivering some 120 cub. ft. per minute would be :—

$$\frac{120}{60 \times 30} \times 144 = 9 \cdot 6 \text{ sq. in.},$$

or a diameter of pipe about $3\frac{1}{2}$ in.

N.B.—Further information will be found on p. 378.

Table 69.—*Air Compressors.*

Diameter of air cylinder..	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.
Piston speed 300 ft. per minute.						
Theoretical volume of air entering cylinder, in cub. ft. per min	165	235	321	420	531	655
Actual volume taken, 25% less, in cub. ft.	124	177	241	315	399	492
Volume of air delivered at 60 lb., in cub. ft.	24·8	35·4	48·2	63·0	79·8	98 4
Volume of air delivered at 70 lb., in cub. ft.	21·8	31·2	42·5	55·5	70·4	86·8
Piston speed 350 ft. per minute.						
Theoretical volume of air entering cylinder, in cub. ft. per min.	192	273	372	487	616	764
Actual volume taken, 25% less, in cub. ft.	144	205	279	366	462	573
Volume of air delivered at 60 lb., in cub. ft.	28·8	41·0	55·8	73·2	92·4	114·6
Volume of air delivered at 70 lb. in cub. ft.	25·4	36·1	49 2	64·5	81·5	101·1
Piston speed 400 ft. per minute.						
Theoretical volume of air entering cylinder, in cub. ft. per min.	220	313	428	560	708	873
Actual volume taken, 25% less, in cub. ft. per min.	165	235	321	420	531	655
Volume of air delivered at 60 lb., in cub. ft.	33	47	64·2	84	106·2	131
Volume of air delivered at 70 lb., in cub. ft.	29·1	41·4	56·4	74·1	93·6	115·5
Number of 3-in. drills the compressor will drive..	2	4	6 to 8	8 to 10	10 to 12	14 to 16
Number of $3\frac{1}{2}$ in. drills the compressor will drive ..	1 to 2	2 to 3	4 to 5	5 to 6	6 to 8	10 to 12
Nominal H.P.	8	12	18	25	30	40
Size of receiver, diameter and lengths	3 × 6 ft.	3 × 8 ft.	$3\frac{1}{2}$ × 8 ft.	$3\frac{1}{2}$ × 10 ft	4 × 12 ft.	$4\frac{1}{2}$ × 15 ft.
Diameter of air main ..	2 in.	$2\frac{1}{2}$ in.	3 in.	$3\frac{1}{2}$ in.	4 in.	5 in.
Price of compressors with ordinary poppet valve, £	184	226	289	334	397	492
Price of high class compressor with patent valves .. .. £	276	340	434	500	592	738
Ditto, receiver .. £	20	30	35	45	55	65
„ boiler .. .. .. £	100	125	175	220	260	350
„ donkey pump £	15	18	20	25	25	30
„ ordinary connections .. .. £	10	12	15	20	20	25

BLASTING.

In blasting, rock requires from ·25–1·5 lb. gunpowder per cub. yd., according to its degree of hardness and position. In small blasts 2 cub. yd. have been rent and loosened, and in very large blasts 2–4 cub. yd. have been rent and loosened, by 1 lb. powder.

Tunnels and shafts require 1·5–2 lb. per cub. yd. of rock.

Gunpowder has an explosive force varying from 40,000 to 90,000 lb. per sq. in. That used for blasting is much inferior to that used for projectiles, the proportion being fully one-third less.

Nitro-glycerine is an unctuous liquid, which explodes by concussion, an extreme pressure (2000 lb. per sq. in.), or a temperature exceeding 600° if quickly applied to it; it will inflame, however, and burn gradually.

At a temperature below 40° it solidifies in crystals.

Its explosion is so instantaneous that in rock-blasting tamping is not necessary; its explosive power by weight is 4–5 times that of gunpowder.

Dynamite is nitro-glycerine 75 parts, absorbed in 25 parts of a siliceous earth termed kieselguhr: it also explodes so instantaneously as to render tamping in blasting quite unnecessary.

It is insoluble in water, and may be used in wet holes; it congeals at 40°, is rendered ineffective at 212°, and has an explosive force by weight of 3 times that of gunpowder, and by bulk 4·25 times.

Gun-cotton is insoluble in water, and has an explosive force by weight of 2·75–3 times that of gunpowder, and by bulk 2·5 times. It may be detonated in a wet state with a small quantity of dry material.

Tonite is nitrated gun-cotton, and is known also as cotton powder. It is produced in cartridge form.

Litho-fracteur is a nitro-glycerine compound in which a portion of the base or absorbent material is made explosive by the admixture therein of nitrate of baryta and charcoal.

Cellulose Dynamite is when gun-cotton is used as the absorbent for nitro-glycerine; it will explode frozen dynamite, and is more sensitive to percussion than it.

To Compute Charge of Gunpowder for Rock Blasting.

Rule.—Divide cube of line of least resistance by 25 as for limestone, to 32 for granite, and quotient will give charge of powder in lb. Or,

$$L^3 \div 32 = \text{lb.}$$

Example.—When line of least resistance is 6 ft., what is charge required?

$$6^3 \div 32 = 6 \cdot 75 \text{ lb.}$$

Line of least resistance should not exceed ·5 depth of hole.

Tamping.—Dried clay is the most effective of all materials for tamping; broken brick the next, and loose sand the least.

Table 70.—*Weight of Explosive Materials in Holes of different Diameters per inch of Length.*

Diameter.	Powder or Guncotton.	Dynamite.	Diameter.	Powder or Guncotton.	Dynamite.
in.	oz.	oz.	in.	oz.	oz.
1	·419	·67	2·25	2·12	3·392
1·25	·654	1·046	2·5	2·618	4·189
1·5	·942	1·507	2·75	3·166	5·066
1·75	1·283	2·053	3	3·769	6·03
2	1·675	2·68			

Table 71.—*Boring Holes in Granite.*

Diameter of Jumper.	Depth of Hole.	Men.	Depth bored per Day.	Hammer.
in.	in.	No.	ft.	lb.
1	1 to 2	1	8	6
1·75	2·5 to 6	3	12	14
2	4 to 7	3	8	14
2·25	5 to 10	3	6	16
2·5	9 to 12	3	5	16
3	9 to 15	3	4	18

Drill.—Width of bit compared to stock, ·625.

Charges of Powder.

Usual practice of charging to one-third depth of hole is erroneous, inasmuch as volume of charge increases as square of diameter of hole. Hence holes of 1·5 and 2 in., although of equal depths, would require charges in proportion of 2·25 and 4.

Line of Least Resistance.	Powder.	Line of Least Resistance.	Powder.
ft.	lb. oz.	ft.	lb. oz.
1	0 0·75	5	3 14·5
2	0 4	6	6 12
	0 13·5	7	10 11·5
	2 0	8	16 0

Effects.

Gunpowder, from its gradual combustion, rends and projects rather than shatters.

A hole 5·5 in. diameter and 19 ft. 7 in. deep, filled to 8 ft. 10 in. with 75 lb. powder, has removed and rent 1200 cub. yd., equal to 2400 tons. The labour expended was that of 3 men for 14 days.

Temperature of gases of explosion 4000°.

Gun-cotton, from the rapidity of its combustion, shatters.

Dynamite, from the greater rapidity of its combustion over gun-cotton, is more shattering in its explosion.

In small blasts 1 lb. powder will loosen about $4\frac{1}{2}$ tons. In large blasts 1 lb. powder will loosen about $2\frac{3}{4}$ tons.

One man can bore 50–100 in. per day in granite, or 300 to 400 in. per day in limestone.

In small charges of dynamite, weak caps seem to develop the full strength of the explosive; but in large charges stronger caps are necessary. Gun cotton and gelatine dynamite require much stronger caps than those ordinarily used for dynamite. Gun cotton seems to produce a more rending explosion than dynamite. The statement made on good authority that black powder fired with a detonator is much more powerful than when fired by fuse alone, has been disproved.

Explosives and Firedamp.

The possibility of firing firedamp by the flame of a shot depends on the greater or less intensity of the flame. This intensity depends especially on the time which is necessary to produce the complete combustion (vaporisation) of the explosive. Inversely to the force of the explosive, this intensity increases with the length of time required for the explosive particles to become incandescent at the time of their decomposition and to form combustible gases.

Gunpowder burns slowly, and it is a well-known fact that particles of powder still in combustion or still uninflamed, may be projected for a long way by the flame jet. According to Trauzl, the rapidity of combustion of a grain of gunpowder is never greater than 10 mm. per second, and the rapidity with which the flame is propagated from particle to particle not more than 10 m. per second. A cartridge 1 ft. in length would therefore require $\frac{1}{30}$ second in order to be in full combustion, whilst the different particles, admitting they were only 1 mm. in diameter, would require $\frac{1}{10}$ second in order to burn completely. But on account of the violent pressure of the explosive gases, especially when the charge is too strong or the tamping defective, it is possible at the end of $\frac{1}{10}$ second to have several jets of flame several yd. in length, which are often sufficient to inflame the firedamp which may be within their reach. In proportion as the powder is coarse, and burns slowly, is it more dangerous. The use of compressed powder recommended by the

Explosives—continued.

French Commission is not satisfactory, and Trauzl admits rightly that in the presence of firedamp this powder is highly dangerous. The statement of gunpowder manufacturers that the danger of gunpowder, both ordinary and compressed, would be eliminated if the charge were fired by strong capsules, such as are used for dynamite, was by no means verified in the Neunkirchen experiments.

Other explosives of great rending force, such as dynamite, gun-cotton, &c., act altogether differently. According to Trauzl long charges of compressed guncotton or dynamite fired at one extremity by means of strong capsules, detonate even in a free state, at the enormous rapidity of 5000–6000 m. per second, and a dynamite cartridge 1 ft. in length explodes in $\frac{1}{5000}$ second. Owing to this marvellous rapidity of propagation, and which also accounts, as is well known, for the violent effects of these explosives, the possibility of inflaming the firedamp, if not completely excluded, is, at least, undoubtedly limited. The incandescence of the decomposed explosive particles is of such short duration, especially when the tamping and capsules are good and efficient, that the flame hardly passes beyond the mouth of the borehole. It is not only the results of the Neunkirchen experiments which confirm the difference in the rapidity of action between gunpowder and other explosives such as those mentioned above; but the practical experiments of the English Commission on Accidents in Mines, and the Saxon Commission, also yielded precisely similar results. We gather from all these experiments that, though the danger of firing firedamp and coal dust through the use of gunpowder for blasting purposes is very great, yet the danger is greatly reduced, if not altogether averted, by the use of other explosives of a more rapid action, provided that there are not exceptional accumulations of gas.

Under these circumstances the Prussian Commission considers that, from the point of view of security, the use of gunpowder should be absolutely interdicted in fiery mines, and that the use of other explosives should be tolerated, provided that the proportion of firedamp does not pass beyond a dangerous limit easy to recognise. It enjoins as follows:—"That the use of gunpowder and other slow explosives should be forbidden in fiery mines, and the use of dynamite and other explosives which act in the same way as dynamite in the presence of coal dust should be authorised only. The use of dynamite should be equally forbidden in those portions of a mine where, under ordinary circumstances, accumulations of firedamp cannot be avoided, nor their presence easily indicated by the aid of the safety lamp."

Amongst explosives of a rapid action, those of a nitro-glycerine character are the best known and most used in coal working. Such are dynamite, No. 1 kieselguhr, and dynamite cellulose, dynamite Nobel, Nos. 2, 3, and 4, dualine, explosive gelatine, gelatine dynamite. Also nitro-cellulose (gun-cotton, &c.), Schultze's

Explosives—continued.
powder, kinetite. and others, such as hellhoffite (explosive Sprengel) carbonite, anagone, securité, and roburite, &c. According to the Neunkirchen experiments dynamite-guhr appears to be the least secure against inflammation of firedamp and coal dusts, because it was found that the mixture could be fired with only 4½ per cent. of gas. On account of the mixture of nitro-glycerine with the inert kieselguhr, the rapidity of propagation of the flame in the dynamite cartridge is diminished, and particles of this projected by the violence of the explosion, and in a state of incandescence, increase the action of the flame. It is easy to conceive that in the driving of a cross-cut yielding a good deal of gas, the gas must be ignited by the flame of the dynamite. This has frequently been observed in the Obernkirchen mines, and the Westphalia Mine, near Dortmund. The mixture of combustible powder with dynamite appears to exert an influence on the safety of the latter, but this influence is only felt in the presence of a large proportion of powder. Thus, whilst unmixed explosives, such as gunpowder, explosive gelatine, hellhoffite, &c., as well as kinetite and dynamite-gelatine No. 1—which only contains 35 per cent. of powder—proved themselves absolutely without danger, in the Neunkirchen experiments, even in the presence of 10 per cent. of firedamp and coaldust, dynamite-gelatine No. 3 (75 per cent. of mixed powder) produced inflammation in the presence of 6 per cent. of firedamp. The Administration of Mines of Saxony obtained similar results with dynamite-guhr and dynamite-gelatine at the time of its experiments at Brückenberg, Shaft No. 1, near Zwickau, in the summer of 1885. Some new experiments under the direction of the Royal Inspection of Mines at Neunkirchen were productive of remarkable results, illustrative of the action of explosives invented of late years. Schultze's powder, of great exploding power, was found to be harmless in the presence of firedamp and coaldust, whilst other qualities of the same powder, such as the explosive known as anagone, were not so secure. The explosive known under the name of securité also appeared to be of a harmless description in the presence of firedamp and coaldust, but, like Schultze's powder, it is hygroscopic, and cannot be used in a moist state. Carbonite, manufactured by Schmidt and Bichel, Berlin, appeared to yield satisfactory results from every point of view, and it seems likely that this explosive will be used instead of gunpowder in fiery mines, chiefly because it is able to contend advantageously with it as regards net cost.

SHAFT-SINKING.

Table 72.—*Cost of Boring and Tubbing Nos. 1 and 2 Pits, Marsden Colliery, by the Kind-Chaudron Process.*

	Construction.									Working.									Summary.		
	Preparing and Erecting Baraque.*		Tools.†	Lining Tube.		Tubbing.	Patent.‡	Total.		Boring.		Repairing Tools.		Tubbing.	Sundries, Salaries, &c.		Total.				
	Labour.	Materials.	Materials.	Labour.	Materials.	Materials.	Materials.	Labour.	Materials.	Labour.	Materials. Stores.	Labour.	Materials.	Labour.	Labour.	Materials.	Labour.	Materials.	Labour.	Materials.	Grand Total.
	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£
No. 1 Pit (12 ft. diam.)	694	654	588	175	644	4491	1062	869	7439	2033	577	825	282	457	3708	722	7023	1581	7892	9020	16,912
No. 2 Pit (13 ft. diam.)	694	654	588	Nil	Nil	5916	1037	694	8195	1765	278	660	261	125	1723	216	4273	755	5967	8950	14,917

* The baraque was originally erected at No. 1 pit; it was taken down and rebuilt at No. 2 pit. The total cost is divided over both pits.

† The original cost of the tools was 2060*l.*; after the completion of the pits they were sold for 984*l.* The difference is divided over both pits.

‡ Patent right (including plans and specifications).

PUMPING.

Horse-power required to Pump 1 gal. of Water against Various Pressures, allowing 40 per cent. for friction.

Pressure per sq. in.	Calculated with 40 per cent. added.	Horse-power required.
700	0·68	say ·75
1,500	1·47	„ 1·75
2,240	2·19	„ 2·5

Useful Numbers for Pumps.

D = Diameter of pump (in.).
S = Stroke of pump (in.).
$D^2 S \times \cdot 7854$ = cub. in.
$D^2 S \times \cdot 002833$ = gal.
$D^2 S \times \cdot 0004545$ = cub. ft.
$D^2 S \times \cdot 02833$ = lb. fresh water.

To find Diameter of Single-acting Pump.

L = Length of stroke in ft.
G = Number of gal. to be delivered per minute.
F = Number of cub. ft. to be delivered per minute.
N = Number of strokes per minute.
D = Diameter of pump (in.).
$F = \cdot 00545\ D^2\ L\ N.$
$G = \cdot 034\ D^2\ L\ N.$

$$D = \sqrt{\frac{G}{\cdot 034\ L\ N}}.$$

$$D = \sqrt{\frac{F}{\cdot 00545\ L\ N}}.$$

Note.—These formulæ give the net diameter of the pump-plunger; it is usual to increase the area of the plunger ¼, to allow for leakage, &c.

Setting up and Running Steam Pumps.

Never use a smaller pipe on the suction than the list indicates.
Avoid right angles in the pipe where it is possible.
Where it is practicable, make bends with a large radius.
Put a foot valve and strainer on the end of the suction pipe.
Do not place the pump more than 29 ft. from the water.
Where hot water is pumped, the supply must be above the pump.

Steam Pumps—continued.

Make all joints in the suction pipe tight.

A small leak in the suction is very detrimental.

Keep the stuffing boxes nicely packed.

Oil the pump before starting it, and keep the oil wiped off where it is not needed.

A good pump is as worthy of being taken care of as a good engine; spend a few moments every day in cleaning them up, removing all extra oil from them, wiping off the dust and dirt, and see that they are in good condition and working well.

Pumping Engines.

G = Number of gal. to be raised in 24 hours.
F = Number of cub. ft. raised in 24 hours.
h = Height in ft. to which the water is to be raised.
HP = Actual horse-power required.

$$HP = \frac{G \times h}{4752000} \text{ or } \frac{F \times h}{762088}.$$

20 per cent. must be added to overcome friction, &c., and 50 or 60 per cent. more is usually allowed for contingencies, making a total of 70 or 80 per cent. additional power.

To find Horse-power of Pumping Engines.

Let G = the number of gal. required per hour; C = the number of cub. ft. required per hour; F = the height in ft. to which the water is to be raised = horse-power.

$$\text{Then} = \frac{G \times F}{198{,}000} \text{ or } = \frac{C \times F}{31{,}750}.$$

About 70 or 80 per cent. must be added to the number obtained by the above formula, to allow for frictional and other contingencies; the result obtained by the formula is not in nominal but in actual horse-power (33,000 foot-pounds).

Table 73.—Power required to Raise Water from Deep Wells.

Gal. of water raised per hour ..	200, 350, 500, 650, 800, 1,000
Height of lift for one man working on crank in ft.	90, 52, 36, 28, 22, 18
Height of lift for one donkey working on gin in ft. ..	180, 102, 72, 56, 45, 36
Height of lift for one horse working on gin in ft... ..	630, 357, 252, 196, 154, 126
Height of lift for one horse-power steam engine in ft. ..	990, 561, 396, 308, 242, 198

This table is based on the assumption that a good class of treble or double-barrel lift pump is used, with valves in the buckets, with an additional retaining valve for lifts above 100 ft.

To find Pressure per sq. in. of a Column of Water (Telford).—Multiply the height in ft. by ·434. The pressure per circular in. may be found by multiplying the height in ft. by ·341. *Ex.*—Required the pressure in lb. per sq. in. of a column of water 200 ft. high.

$$200 \times \cdot 434 = 86 \cdot 8 \text{ lb. per sq. in.}$$

A ready way of approximately ascertaining the pressure is to take half the height in ft.

To find Pressure of a Column of Water in lb.—If the base be circular, square the diameter in inches, and multiply by ·341, which gives the weight of 1 ft. in height; by multiplying by the number of ft. in height, the pressure is found. If the base be square, multiply by ·434. *Ex.*—Required the pressure of a column of water 12 in. diameter and 20 ft. high.

$$12 \times 12 \times \cdot 341 \times 20 = 982 \cdot 080 \text{ lb. if the base be circular.}$$
$$12 \times 12 \times \cdot 434 \times 20 = 1 \cdot 249 \cdot 920 \text{ lb. if the base be square.}$$

To find Quantity of Water in a Pipe.—The square of the diam. in inches gives the weight of water in lb. for 3 ft. in length, and by striking off one figure to the right the number of gal. is found. *Ex.*—Required the quantity of water which a pipe 15 in. diameter and 9 ft. long will contain :—

$$15 \times 15 \times 3 = 675 \text{ lb., or } 67 \cdot 5 \text{ gal.}$$

To find Diameter of Pipe required to Discharge a Given Quantity of Water at a Given Speed per Minute.—RULE: Multiply the

number of cub. ft. of water per minute by 144, and divide by the velocity of flow in ft. per minute; divide by ·7854, and take out square root, which will give diameter of pipe.

To find Velocity of Flow of Water in a Pipe required to Discharge a Given Volume of Water in a Given Time.—RULE: Multiply the number of cub. ft. of water by 144, and divide the product by the area of the pipe in inches.

Centrifugal Pumps.

Centrifugal pumps and direct acting pumping engines are largely employed in the mining industry, and as their usefulness becomes better known their employment will be extended. On moderate lifts, such as those prevailing in alluvial mines, no better water elevator can be adopted (1) on account of their great efficiency; (2) because, in the absence of valves, they will pass mud, grit, chips, &c., without detriment to their working; (3) by reason of their very low first cost and trifling cost of repairs. The "Invincible" pumping engine, made by John and Henry Gwynne, of Hammersmith Ironworks, and Cannon Street, London, is claimed to be, on certain lifts, more economical than any pump of the centrifugal or other type, or than scoop wheels, or any other water-raising appliance known.

Pulsometers.

The distinguishing features of the pulsometer are briefly as follow:—The pump itself is not subject to wear like other pumps. The only wearing parts (the valves) can be readily and cheaply renewed. Such renewals are needed only at long intervals. No expense for skilled labour. Whilst on constant work the pulsometer will run for long periods unseen. It requires no oil, tallow, packings, or foundations. Will work equally well suspended on a chain as when fixed, and can be used whilst being lowered. For sinking work the great advantage of this capability will be readily recognised. The pulsometer will go into a smaller space than any other pump of equal capacity. Having no exhaust steam, it can be used in confined spaces without heading them up, as is the case with ordinary steam pumps. The pump is noiseless in operation. They will pump very dirty water and a great variety of other liquids and semi-liquids to a total height of 70–80 ft., or under special circumstances to much greater heights. They are best adapted to a suction not exceeding 6–10 ft. for the smaller size, and 10–15 ft. for the larger. These figures are, of course, modified by circumstances, as pulsometers are occasionally used on very much higher lifts, but the above may be safely taken as a guide. As a convenient guide also it may be stated that the pressure of steam at the pump for lifts of 20–40 ft. should not be less than 20–30 lb. per sq. in., and for lifts of 40–80 ft. not less than 30–50 lb. For

Pulsometers—continued.
higher lifts greater steam pressure is necessary. The pulsometer can be made in gunmetal, to withstand the action of bad water sometimes met with in mines. The advantages enumerated as belonging specially to the pulsometer in its portability, its ability to raise very dirty water, &c., without injury, its small size, cost, and general handiness, have already established its reputation for all kinds of pumping in mines, &c. If desired, for lifts above 90–100 ft., the discharge of one pulsometer may be taken into the suction of another pulsometer placed above; or a small tank may be placed midway, the bottom pump discharging into it and the higher one drawing from it. Either of these arrangements is used with great success, and in this way a large number of very awkward sinking jobs have been performed. For lifts above the range of the pulsometer, the "Deane" Patent Double-Plunger Sinking Pump is strongly recommended. It will pump gritty water to almost any height; is strong and very simple. It can also be made in small parts for easy transit in mountainous countries.

Table 74.—*Pulsometers.*

No.	Height of Pulsometer.	Space occupied.	Size of Steam Supply Pipe.	Size of Suction Pipe.	Size of Discharge Pipe.	Imperial Gallons per Hour.
	in.	in.	in.	in.	in.	
1	18	10 × 10	¼	1½	1	900
2	22	15 × 13	¼	2	1½	2,000
3	28	23 × 15	½	3	2	3,800
4	32	24 × 20	½	3½	2½	6,000
5	39	25 × 25	¾	4	3	10,000
6	42	27 × 27	1	4½	3½	13,000
7	48	32 × 26	1¼	5	4	17,000
7½	51	39 × 28	1¼	5	4	22,000
8	56	39 × 32	1¼	6	5	28,000
9	66	39 × 36	1½	7	6	40,000
10	79	48 × 42	2	8	7	52,000
11½	80	56 × 42	2	10	8	80,000

The quantities are given on a total lift of about 20 ft.

VENTILATING.

Table 75.—VENTILATING: *Efficiencies of Mechanical Ventilators.* (N. Eng. Inst. Min. Engs.)

No.	Name of Ventilator.	Dimensions of Ventilator.					Dimensions of Engines.				General Results.		
		Diameter.	Width, &c.	Theoretical Displacement per Minute.	Diameter of Inlet.	Weight.	No. of Cyls.	Diam. of Cylinders.	Length of Stroke.	Direct-acting or Geared.	Volume of Air per Minute.	Mean Water Gauge at Drift Door.	Percentage of Useful Effect.
		ft. in.	ft. in.	cub. ft.	ft. in.	tons		in.	ft. in.		cub. ft.	in.	
1	Guibal ..	Fan .. 50 0	.. 12 0	..	15 0	50	1	42	3 6	Direct.	108,422	3·30	40·00
2	„ ..	„ .. 46 0	.. 14 10	..	13 0	..	1	36	3 6	„	246,509	1·85	52·95
3	„ ..	„ .. 40 0	.. 12 0	..	14 0	24	1	36	3 0	„	170,581	1·46	47·95
4	Waddle..	„ .. 45 0	Inlet .. 6 6 Periphery 1 5	..	15 0	..	1	32	4 0	„	163,312	3·08	52·79
5	Schiele ..	„ .. 12 0	.. 2 1	..	..	..	1	25	2 0	2·57 to 1	157,176	1·91	46·12
6	„ ..	„ .. 9 6	Inlet .. 3 2 Periphery 1 8	..	8 0	..	1	20	1 8	2¼ to 1	106,570	2·03	49·27
7	Lemielle	Chamber 22 6 Drum .. 15 0	Height 32 0	9·9 rev. 108,900	..	..	1	55	6 0	Direct	47,307	1·37	23·40
8	Struvé ..	2 pistons 18 3	Stroke 7 0	6·50 „ 47,827	..	..	1	24	4 4½	4 to 1	43,793	5·11	57·80
9	Nixon ..	2 pistons— Long.. 30 0 High.. 50 0	Stroke 7 3	7·19 „ 120,790	..	..	1	36	6 0	Direct	72,595	2·74	45·91
10	Root ..	2 drums 25 0	.. 13 0	16·71 „ 96,918	..	..	2	28	4 0	„	89,772	3·29	47·84
11	Cooke ..	2 drums 15 0 Casing .. 22 0	.. 11 6	17·92 „ 80,640	..	..	1	25	3 6	„	54,190	1·12	37·33
12	Goffint ..	2 pistons 13 2	Stroke 10 7¾	9·25 „ 53,020	..	..	2	15¾	10 7¾	„	36,286	0·71	25·79

Table 76.—VENTILATING: *Duty of Furnaces at Collieries in Northumberland and Durham Coalfield.* (Cochrane.)

Name of Colliery.	Downcast Shaft.		Upcast Shaft.		Area of Furnace Grate.	Temperature of Air.						Volume of Air circulated per Minute.	Water Gauge in the Mine.	Coal consumed in 12 Hours.	Consumption of Coal per Hour per H.P. in the Air.
	Diam.	Depth.	Diam.	Depth.		Top of Downcast.	Bottom of Downcast.	Return Air near Furnace.	Bottom of Upcast.	Half-way in Upcast.	Top of Upcast.				
	ft.	yd.	ft.	yd.	sq. ft.	Fahr.	Fahr.	Fahr.	Fahr.	Fahr.	Fahr	cub. ft.	in.	cwt.	lb.
Rugeley	12	160	12	160	64	..	..	61	141	117	110	103,325	0·62	40	37·0
North Seaton ..	15¼	250	9	266	72	68	70	65	225	206	186	99,750	1·10	91	49·2
Ryhope..	15	508	10¼	460	160	62	..	76	170	..	134	126,336	1·00	120	56·3

VENTILATING: *Cost of Supplying Air by Different Systems.* (Forster.)

The following are the figures obtained for 100 cub. metres per minute. The use of steam as a motive power, at a cost of 12*l.* 10*s.* per gross H.P. per annum, is assumed:—

Compressed air at 3 atmospheres excess pressure; velocity of current 10 metres per second, escaping at full pressure from the air-pipe, 230 mm. diameter, cost 9235*l.* per annum. The same using a Körting blower, and pipes 89 mm. in diameter, 1510*l.* The same using a compound engine, Root's blower, and pipes of 50 mm., 365*l.*

Branch current taken from main fan pressure, 0·001 atmosphere or 10 mm. water gauge; 2 metres per second velocity of current, pipes 1030 mm. diameter, 210*l.* This, on account of the low velocity of current and the large size of pipes, would be practically useless at the distance of 1000 metres from the fan.

Current produced by a special high speed fan at surface $\frac{1}{40}$ atmosphere, or 250 mm. pressure, velocity per second 6 metres, pipe 585 mm., cost 380*l.*

Current of 10 metres per second at $\frac{1}{10}$ atmosphere, 1033 mm. pressure, pipes 454 mm., produced by a series of two or three fans, or a cylinder blowing engine. The cost in the first case is 725*l.*, and in the second 870*l.* per annum; or, where the pressure is increased to $\frac{1}{4}$ atmosphere, 1510*l.* and 1935*l.* These are, however, only approximations, from very restricted data.

Electric transmission of power to mine ventilators working at low pressure; no pipes required; old pit ropes used as conductor.

VENTILATING: *Formulæ.*

(1) t = temperature of air in downcast shaft.
T = temperature of air in upcast shaft.
D = depths of the shaft in ft.
m = the periphery of the transverse section of the air-course in ft.
s = the area of the section in ft.
l = the length traversed by the current in ft.
v = the velocity of the current in ft. per second.

$$v = 96\sqrt{\frac{\frac{(T-t)}{T+448}Ds}{ml+368s}}$$

(2) C = length of downcast column.
c = length of upcast ditto.
T = number of degrees in excess of 32° F. in C.
t = number of degrees in excess of 32° F. in c,

$$c = C\left(\frac{480+t}{480+T}\right).$$

LIGHTING.

Table 77.—LIGHTING: *Relative Cost of Artificial Illumination by different Systems at a Colliery raising* 1000 *tons a day.*

Electric Light.

	c. p.		hours per day.	lamp hours per annum.
1. Pit head, 2 × 200 c. p.	= 14 × 16	averaging ..	10 ..	= 40,600
2. Winding engine, fan, boilers, pumps, &c.	= 12 × 16	" ..	10 ..	= 34,800
3. Shops, offices, &c.	= 16 × 16	" ..	1½ ..	= 6,960
4. Screens, sorting, &c., 4 × 200 c. p.	= 28 × 16	" ..	1½ ..	= 12,180
5. Underground	= 20 × 16	" ..	10 ..	= 58,000
6. " (continuous lighting)	= 10 × 16	" ..	24 ..	= 69,600
	100 × 16			222,140

The total candle power is about 2124, though with electric light this will be more effective than with other lights, on account of the greater facilities for reflection. To get the I.P.H. per annum we may divide the total lamp hours by 10, since each 16 c. p. lamp takes $\frac{1}{10}$ I.P. Allowing 10 lb. of slack coal per I.P.H. at 1*s.* 6*d.* per ton—

	£	*s.*	*d.*
Electricity.—Coal, 100 tons, at 1*s.* 6*d.*	7	10	0
Renewals of lamps at 1500 hours' burning (they usually last for 2000 hours):—			
2900 hours. 1. 2 × 200 c. p. lamps renewed twice at 18*s.* each ..	3	12	0
2900 " 2. 12 × 16 " " " " 4*s.* " ..	4	16	0
435 " 3. 16 × 16 " " $\frac{1}{3}$ times " 4*s.* " ..	1	1	4
435 " 4. 4 × 200 " " $\frac{1}{3}$ " " 18*s.* " ..	1	4	0
2000 " 5. 20 × 16 " " twice " 4*s.* " ..	8	0	0
6960 " 6. 10 × 16 " " four times " 4*s.* " ..	8	0	0
Interest and depreciation at 10 per cent. on capital outlay—200*l.* ..	20	0	0
Oil, water, waste, &c...	5	0	0
	£59	3	4

The total cost of electric lighting will therefore be about 60*l.* per annum, and this on 290,000 tons per annum will be ·05*d.* per ton raised.

Gas.—With gas, the capital outlay may be taken, for main, pipes, and fittings, at about 150*l.*

At 3 c. p. per cub. ft. per hour, and 5 ft. per 15 c. p. lamp:—

		£	*s.*	*d.*
1. 40,600 lamp hours at 5 cub. ft.	= 203,000 cub. ft.	25	7	6
2. 34,800 " "	= 174,000 "	21	15	0
3. 6,960 " "	= 34,800 "	4	7	0
4. 12,180 " "	= 60,900 "	7	12	3
5. 58,000 " "	= 290,000 "	36	5	0
6. 69,600 " "	= 348,000 "	43	10	0
Taking the cost at 6*d.* per 1000 cub. ft. Total cost of gas		138	16	9
Interest and depreciation on 150*l.* at 10 per cent.		15	0	0
		£153	16	9

Gas—continued.

On the same amount of coal per annum, viz. 290,000 tons, this will be about ·13*d.* per ton raised.

Paraffin.—With paraffin, taking 2 × 1¼ in. wick duplex lamps as 16 c. p., consuming $\frac{1}{10}$ pint of oil (at 8*d.* per gal.) per hour.

	£	s.	d.
1. 40,600 lamp hours = 507·5 gal.	16	18	4
2. 34,800 " = 435 "	14	10	0
3. 6,960 " = 87 "	2	18	0
4. 12,180 " = 152·25 "	5	1	6
5. 58,000 " = 725 "	24	3	4
6. 69,600 " = 870 "	29	0	0
Total cost of oil	92	11	2
Wick, say	3	0	0
Labour, trimming, &c.	25	0	0
Interest on capital outlay of, say, 80*l.* at 5 per cent.	4	0	0
Depreciation, repairs, and breakages, at 20 per cent. on 80*l.*	16	0	0
	£140	11	2

On 290,000 tons raised, this amounts for oil to ·116*d.* per ton, for gas to ·13*d.* per ton, and for electricity to ·05*d.* per ton.

Thus it will be seen that electricity compares very well as to cost with other illuminants, since gas costs nearly three times and oil more than twice as much for the same amount of illumination.

Thorneburry Miners' Safety Lamp.

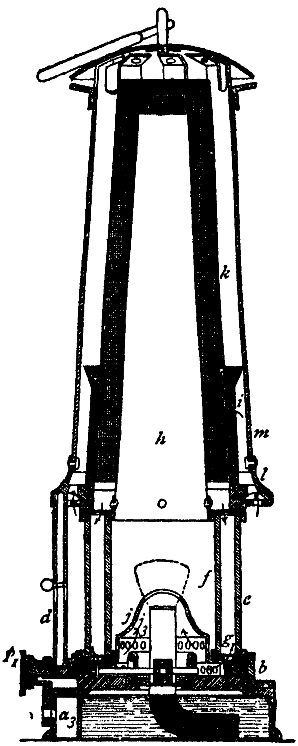
The Thorneburry lamp promises to exceed all previous lamps of the same class in the amount of light which it gives, and in the security which it will afford in an explosive atmosphere. The fuel of the lamp is heavy petroleum oil, having a flashing point of 250°, and it is burned under a cone of the familiar form which obtains in paraffin lamps. The whole of the air-supply is delivered into this cone, and most of it passes through the slot in the top, making a sharp draught, which steadies and brightens the flame. The illumination afforded is 1–1½ candles, which is three or four times that of a modern safety-lamp, a most valuable feature, as the miner's ability to detect dangerous spots in the roof depends to a great extent upon the amount of light at his command. The wick can be raised and lowered by a pinion and milled disc in the usual way, but as the gas given off by the oil does not burn in actual contact with the wick, the latter needs very little adjustment, and need not be disturbed for hours.

Referring to Fig, 10, it will be seen that the oil reservoir forms the base of the lamp, and is screwed into the ring *b*. This ring is connected to an upper ring by a number of columns *d*. Between the two rings are fixed two concentric glass cylinders *e f*, so secured that they are not disturbed when the lamp is taken to pieces for cleaning. To the top of the upper ring is screwed the chimney and its case. The air to support combustion enters

Safety Lamp—continued.

through holes in the upper ring, and passing the gauze screen *v* travels downwards between the glass cylinders *e f*. At the bottom it passes through a ring of gauze g^1, and then through perforations in the base *b*, after which it enters the cone. The products of combustion rise up the chimney *h*, and escape through openings at the top of the case, first passing through the gauze cone *k*. This latter, however, is not necessary for safety. The lamp is self-extinguishing in an explosive mixture, the gas and air entering the lamp cone being ignited by the flame and consumed before it reaches the chimney. Both the lamp flame and the ignited gas are automatically extinguished by the after-damp or carbonic acid gas, which is produced in the cone by the ignition of the explosive mixture. Hence it is obvious that the outer gauze enclosing the chimney is not necessary for the safety of the lamp, but is only an additional protection in case of an accident to the bottom gauze ring.

Fig. 10.



Thorneburry Safety Lamp.

The top part of the lamp is locked by a bolt which stands over the pin *p*. So long as the latter is in position the bolt cannot be withdrawn. The pin *p* is again locked by a bayonet joint having a part which can be padlocked or riveted to the oil reservoir. When the locking is complete, the lamp cannot be opened without detection by any ingenuity.

The lamp has been tested by Sir F. Abel and Prof. Dewar, who report that they have conducted a series of laboratory experiments with it, and have witnessed practical trials, which were carried out at the Aldwarke Main Colliery, by Mr. Rhodes, in an apparatus of the same character as was used by the last Royal Commission on Accidents in Mines. They saw the lamp tested in explosive gas mixtures, the velocity of the current being in some experiments as high as 50 ft. per second, or 3,000 ft. per minute; both horizontal

Safety Lamp—continued.
and inclined currents, upwards and downwards, were used. In all instances the lamp was extinguished within a very few seconds after the explosive gas current was established, and on no occasion during the course of the experiments was the combustible gas mixture within the lamp seen to burn. The lamp, therefore, fulfilled the conditions, even under abnormal circumstances, essential to safety in mines, as laid down in the Mines Commissioners' Report. A light of uniform power, which could be so regulated as to equal 1–1½ candle-power, was maintained for many hours with mineral oil of high-flashing point, which, in regard to safety, is not inferior to the animal or vegetable oils used, or to the mixture prescribed by the Mines Commission.

In regard to simplicity of construction, the lamp compares favorably with many of the later and more efficient forms of safety-lamps, and the several parts are readily maintained in a thoroughly clean and efficient condition.

Table 78.—COAL CUTTING: *Comparison of Relative Cost by Hand and Machine.* (G. Blake Walker.)

	In a Seam 36 in. thick. Nature of Holing.			In a Seam 30 in. thick. Nature of Holing.			In a Seam 24 in. thick. Nature of Holing.			In a Seam 18 in. thick. Nature of Holing.		
	Favourable.	Hard.	Very Hard.	Favourable.	Hard.	Very Hard.	Favourable.	Hard.	Very Hard.	Favourable.	Hard.	Very Hard.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Price for getting coal by hand, per ton	1 6	1 7	1 8	1 10	2 0	2 2	2 6	2 9	3 0	3 3	3 7	4 0
Percentage of slack by hand ..	40	40	45	45	45	50	50	50	55	55	55	55
Percentage of slack by machine	20	20	20	20	20	20	25	25	25	30	30	30
Average selling price per ton—	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Round (including nuts), at 6s. per ton .. .. hand	4 7·2	4 7·2	4 5	4 5	4 5	4 3	4 3	4 3	4 1	4 1	4 1	4 1
Slack, at 2s. 6d. per ton machine	5 4	5 4	5 4	5 4	5 4	5 4	5 1¼	5 1¼	5 1¼	4 11¼	4 11¼	4 11¼
Price for filling out coal when coal is holed by machine ..	1 0	1 0	1 0	1 3	1 3	1 3	1 10	1 10	1 10	2 6	2 6	2 6
Yards holed by each machine per day of 16 hours	140	105	70	140	105	70	140	105	70	140	105	70
Holed by 7 machines per day say	tons 1,000	tons 750	tons 500	tons. 830	tons 620	tons 415	tons 666	tons 500	tons 333	tons 500	tons 375	tons 250
Holed by 7 machines in 250 days .. .. say	250,000	190,000	125,000	207,500	155,000	103,750	166,500	125,000	83,250	125,000	93,750	62,500
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Cost per ton (based on previous estimate) for holing by machine..	0 3·1	0 4·2	0 6·3	0 3·8	0 5·1	0 7·6	0 4·8	0 6·3	0 9·5	0 6·3	0 8·4	1 0·6
Total cost of coal getting by machine	1 3·1	1 4·2	1 6·3	1 6·8	1 8·1	1 10·6	2 2·8	2 4·3	2 7·5	3 0·3	3 2·4	3 6·6
Saving, as compared with hand labour	0 2·9	0 2·8	0 1·7	0 3·2	0 3·9	0 3·4	0 3·2	0 4·7	0 4·5	0 2·7	0 4·6	0 5·4
Saving in yield of coal (value)	0 8·8	0 8·8	0 11·0	0 11·0	0 11·0	1 1·0	0 10·5	0 10·5	1 0 5	0 10·5	0 10·5	0 10·5
Total saving	0 11·7	0 11·6	1 0·7	1 2·2	1 2·9	1 4·4	1 1·7	1 3·2	1 5	1 1·2	1 3·1	1 3·9

HAULING AND HOISTING.

HAULING AND HOISTING: *Determination of Qualities and Strength of Ropes from Appearance.*

A good hemp rope is hard, but pliant, yellowish or greenish-grey in colour, with a certain silvery or pearly lustre. A dark or blackish colour indicates that the hemp has suffered from fermentation in the process of curing, and brown spots show that the rope was spun while the fibres were damp, and is, consequently, weak and soft in those places. Again, sometimes a rope is made with inferior hemp on the insides, covered with yarns of good material—a fraud, however, which may be detected by dissecting a portion of the rope, or, in practised hands, by its behaviour in use. Other inferior ropes are made from short fibres, or with strands of unequal length or unevenly spun—the rope in the first case appearing woolly on account of the number of ends of fibre projecting, and, in the latter case, the irregularity of manufacture is evident on inspection by any good judge. A very simple and extremely ready means for ascertaining the purity or otherwise of Manilla hemp rope consists in forming balls of loose fibre of the ropes to be tested, and burning them completely to ashes. While pure Manilla hemp burns to a dull greyish-black ash, Sisal leaves a whitish-grey ash, combinations of Manilla and Sisal yielding a mixed ash resembling the beard of a man turning from black to grey.

Table 79.—*Weights and Strengths of Hemp and Wire Ropes.*

(*a*) FLAT ROPES.

Hemp.		Iron.		Steel.		Equivalent Strength.	
Size in inches.	Weight per fathom.	Size in inches.	Weight per fathom.	Size in inches.	Weight per fathom.	Working Load.	Breaking Load.
	lb.		lb.		lb.	cwt.	tons
4 + 1⅛	20	2¼ + ½	11	..	..	44	20
5 + 1¼	24	2½ + ½	13	..	..	52	23
5½ + 1⅜	26	2¾ + ⅝	15	..	..	60	27
5⅝ + 1½	28	3 + ⅝	16	2 + ½	10	64	28
6 + 1½	30	3¼ + ⅝	18	2¼ + ⅜	11	72	32
7 + 1⅞	36	3½ + ⅝	20	2¼ + ½	12	80	36
8¼ + 2⅛	40	3¾ + 11/16	22	2½ + ½	13	88	40
8½ + 2¼	45	4 + 11/16	25	2¾ + ⅝	15	100	45
9 + 2½	50	4¼ + ¾	28	3 + ⅝	16	112	50
9½ + 2⅜	55	4½ + ¾	32	3¼ + ⅝	18	128	56
10 + 2½	62	4⅝ + ¾	34	3½ + ⅝	20	136	60

Table 79—*continued.*

(*b*) ROUND ROPES.

Hemp.		Iron Wire.		Steel Wire.		Equivalent Strength.	
Circumference.	Weight per fathom.	Circumference.	Weight per fathom.	Circumference.	Weight per fathom.	Working Load.	Breaking Load.
in.	lb.	in.	lb.	in.	lb.	cwt.	tons.
2¾	2	1	1	..	..	6	2
..	..	1½	1½	1	1	9	3
3¾	4	1⅝	2	..	..	12	4
..	..	1¾	2½	1¼	1½	15	5
4½	5	1⅞	3	..	..	18	6
..	..	2	3½	1⅜	2	21	7
5½	7	2⅛	4	1½	2½	24	8
..	..	2¼	4½	..	..	27	9
6	9	2⅜	5	1⅞	3	30	10
..	..	2½	5½	..	..	33	11
6½	10	2⅝	6	2	3½	36	12
..	..	2¾	6½	2⅛	4	39	13
7	12	2⅞	7	2¼	4½	42	14
..	..	3	7½	..	..	45	15
7½	14	3⅛	8	2⅜	5	48	16
..	..	3¼	8½	2½	..	51	17
8	16	3⅜	9	2½	5½	54	18
..	..	3½	10	2⅝	6	60	20
8½	18	3⅝	11	2¾	6½	66	22
..	..	3¾	12	..	..	72	24
9½	22	3⅞	13	3¼	8	78	26
10	26	4	14	..	..	84	28
..	..	4¼	15	3⅜	9	90	30
11	30	4⅜	16	..	..	96	32
..	..	4½	18	3½	10	108	36
12	34	4⅝	20	3¾	12	120	40

HAULING AND HOISTING: *Mine Ropes in England, Belgium, and Germany.* (Aguillon.)

With regard to the material for pit-ropes—whether hemp, or iron or steel wire—and their shape, whether round or flat—the advantage attributed to hemp ropes, of giving warning before they break, is shared equally by wire ropes when properly looked after, and the latter can be employed with as much safety as hemp ropes, when proper care is bestowed upon everything affecting their working. In wet pits, particularly where the water is at all corrosive, or where it is wound up in buckets instead of being pumped, aloes ropes are preferable. But in upcast-shafts, however slightly warm be the air-current, wire ropes should be used, in spite of the disadvantage of their hemp core. In the absence of any such special reasons, the choice of material is more a question of economy and convenience than of safety. Where it is determined that the rope

Mine Ropes—continued.
shall be flat instead of round, the power of the winding engine in deep pits can be better balanced with a hemp rope; because a flat wire-rope is too thin to alter the leverage quickly enough in coiling or uncoiling on the rope roll, and would involve some kind of counterbalance, which would be a matter of difficulty. This is the practical reason why several deep pits in France have recently changed from flat wire-ropes to flat aloes-rope. With wire-rope, too, there is much more difficulty in making a good flat rope than a good round one; and round ropes winding on conical or spiral drums afford a convenient means of balancing the engine-power. As to the choice between steel and iron for wire ropes, German and English practice goes to show that steel ropes well made and of a suitable quality of steel, are capable of working better in all respects, and appear even to be safer. The exclusive use of steel-wire ropes in Germany and England, and of hemp or aloes ropes in Belgium, for all depths of pit, is attributed to the degree of excellence which has been arrived at in the two former steel-producing countries in the manufacture of steel wire of sufficiently homogeneous quality and otherwise suitable for ropes; whereas in Belgium the manufacture of aloes or hemp ropes has always been a special industry of Flanders, where it has attained a rare degree of perfection. The whole of the winding gear should always be carefully adapted to the particular material of which the ropes are made. In France the mistake has generally been committed of ordering a rope without giving the maker any idea of the conditions under which it is to work, the very make being often specified for him in detail. Elsewhere the more sensible practice is to consult with the maker throughout, furnishing him with complete information as to the whole of the requirements to be fulfilled.

In addition to being tested, all ropes should be guaranteed by the makers. In Belgium the guarantee for aloes ropes is generally that they shall last 1½–2½ years, or else for a given output; and 1-12th or 1-24th of their value is deducted for every month short of their stipulated duration. At the Royal Collieries at Saarbrücken, the ropes, of English crucible cast-steel wire, are guaranteed for 6 weeks, during which the maker is held liable to replace them if found defective.

Testing should apply, for hemp and aloes ropes, both to the raw material itself and to the spun yarn, as well as to sample lengths of the finished ropes. The twist of the rope, and the stitching of a flat rope, should be very uniform; and the rope should not contain more than 20 per cent of tar.

Iron wire for ropes should be strong, hard, pliable, and not galvanised, and should be selected from standard makes. Steel wire should be made from crucible cast-steel, of very homogeneous and comparatively hard quality, and suitably annealed; it should have a tensile strength of 70–76 tons per sq. in., and should stretch 3–5 per cent., and be pliable. It should be tested for tensile

Mine Ropes—continued.
strength, stretching, bending, and torsion; and all the wires in the same rope should be as closely alike as possible. Sample lengths of the rope itself should be tested. The lay of the wires and strands should be regular; in flat ropes the stitching should be regular, and should be done with annealed wire. Torsion is considered an excellent test for homogeneous quality in wire: steel wires of 0·509 in. and 0·118 in. diameter should stand twisting through 40 and 20 revolutions respectively in an unloaded length of 6 in.; and the surface markings produced by the twisting should follow regular lines.

The size of the wires, and the length of their lay or pitch in the rope, should vary in accordance with the diameter of the drums and pulleys round which the rope will have to work; and particularly with the distance between the drum and the pit-head pulley, and with the angle which the inclined span winding on the drum makes with the vertical portion hanging down the pit. These are essential points for determining the stiffness requisite to prevent the rope from flapping as it runs.

Experience proves that the very material itself of every rope does certainly undergo deterioration in working, thereby diminishing the rope's strength till it becomes no longer safe. This deterioration of material is something more than mere wear by friction or rusting; in aloes ropes, the fibres lose their strength: and in wire ropes, even where testing fails to show any loss of tensile strength per sq. in. of section, there is a clear diminution of pliability and elasticity; the wires become harsh and brittle, whereby the rope is weakened. Though the deterioration is generally accompanied by unmistakable external indications, it is yet desirable to trace its progress by actual tests of the individual wires, or of the ends of the rope itself.

Large diameters for drums and pulleys are of more importance for wire ropes than for hemp, and for steel than for iron. The smallest diameter should be at least 1300–1400 times that of the iron wire in a rope, and 2000 times that of the steel wire. Its relation to the size of the rope itself matters less, because the disadvantage of too small a diameter can be obviated by selecting a suitable size of wire and by a suitable make of rope. It is well, however, for the smallest diameter of pulley or drum to be not less than 80–100 times the diameter or thickness of a wire rope, and 50 times for a hemp rope.

The rope should wind smooth on the drums or pulleys, without rubbing sideways against them, and so as to run free from jolts and flapping. For wire ropes it is desirable to line the grooves of the pulleys with wood. The larger the diameter of the head-gear pulley, the less does it matter how small be the angle which the inclined span winding on the drum makes with the rope hanging down the pit; but with smaller diameters of pulley the angle should be increased, in order thereby to diminish the bending of the rope

Mine Ropes—continued.

in passing over the pulley. Opinions differ as to the minimum angle to be allowed; some assign 40° as the limit, while according to others it should never be less than 60°. In plan, the obliquity of a round rope between the overhead pulley and the drum should always be kept within the smallest possible limits.

In doubling back the rope end for attaching it to the cage, the loop should be kept as large as possible, by inserting within it an iron eye or a wooden disk; this is particularly advisable with iron wire-ropes, and still more so with steel. The attachment should also be made with springs, for easing the jerk at starting.

Iron or steel wire-ropes of large size should not work at more than one-tenth of their breaking strength; small round ropes may be worked up to one-sixth. Well-made aloes-ropes may be loaded to one-seventh or one-eighth.

Careful maintenance is indispensable to the preservation of all ropes, especially of wire-ropes. Hemp ropes want tallowing regularly, and aloes ropes want keeping always damped. Wire-ropes, steel particularly, should be greased regularly, and often enough to prevent their ever beginning to rust. The grease should be soft enough to work into the strands, right through the hemp cores, but stiff enough to stick on the outside of the rope. A mixture of oil and grease, well stirred and laid on hot with a brush, answers very well; both oil and grease should be neutral.

Iron wire ropes are rapidly being replaced by steel wire, owing to the less weight needed to afford the same strength. But it must be remembered that when the mine water contains much acid, the steel will wear much faster than the iron.

Table 80.—HAULING AND HOISTING: *Underground Haulage.* (N. Eng. Inst. Min. Engs.).

System of Haulage.	Average Gradient for Full Tubs.	[illegible]							
		Ropes or Chains.	Tubs.	Grease and Oil.	Coals.	Repairs to Engines and Boilers.	Maintenance of Way.	Labour.	Total.
Endless chain	Rise 1 in 59	0·083	0·173	0·155	0·256	0·072	0·068	0·572	1·379
Tail rope ..	„ 1 „ 213	0·276	0·114	0·186	0·558	0·098	0·064	0·583	1·879
Endless rope	„ 1 „ 36	0·252	0·309	0·138	0·323	0·196	0·083	1·692	2·993

HAULING AND HOISTING: *Endless Chain Haulage.* (Mowat)

The speed of the chain varies from 1 to 3 miles per hour, the best speed being about 2 miles per hour, although this may be increased with advantage to 3 miles when the output is very large, and the chain is not strong enough to allow of the hutches being placed close together. The distance between the hutches varies from 10 to 25 yd., according to circumstances. If the road is very flat, they might require to be placed as close together as 10 yd. to get sufficient motive power, while, if the incline is steep, 25-30 yd. apart will give ample power. When the distance is greater than 25 yd., however, the chain is liable to trail on the pavement between the hutches, thus causing great tear and wear; so that, if possible, the distance should be shortened that the chain may never touch the ground, except, perhaps, near the lower wheel, where it can hardly be avoided, and where beech planks should be laid to keep it off the pavement. The distance between the hutches is regulated by a small bell, which is placed on the incline at the prescribed distance from the hanging-on place, and which is rung by the last hung-on hutch striking it. The boy at the bottom puts on an empty hutch for every full one that comes off, thus keeping the number on both sides as nearly as possible uniform.

If the speed of the chain be taken as 2 miles per hour, and the distance between the hutches as 15 yd., the total number of hutches run off per hour, if the chain goes constant, would be $\frac{2 \times 1760}{15} =$ $234\frac{2}{3}$ hutches per hour: or, if the hutches hold 10 cwt. each, 117 tons per hour. These figures show clearly that a very large output can be drawn, regardless of the length of the incline, without increasing the speed beyond a creeping pace.

When a change of gradient takes place, so as to form a hollow, the road must be raised in the hollow and the inclination changed gradually, so as to prevent the chain from being lifted out of the catch. In short, the road must be made to follow the natural curve of the chain. When a chain is suspended between two points of support, it forms a catenary curve, but if it is drawn nearly straight between the supports, it may be taken as a parabola, whose axis is vertical, without sensible error. In order to find the parabola which the chain will assume, it is necessary to take into account the tension of the chain at the origin or lowest point of the the curve, the weight of the chain, and the distance between the hutches, all of which are known, or can easily be found.

Let T = tension at O in lb.
w = weight of chain per ft. in lb.
$OH = y = \frac{1}{2}$ span between supports in ft.
x = depression in ft.
wy = approximate weight of chain O P, when O P is nearly straight and level.

Endless Chains—continued.

Then, to find the depression x in the chain between the two hutches,

$$\frac{x}{\frac{1}{2}y} = \frac{w\,y}{T}$$

$$x = \frac{w\,y^2}{2\,T}, \qquad (1)$$

and the equation to a parabola, when y and q are the co-ordinates and 4 A the ratio between x and y^2, is

$$y^2 = 4\,A\,x,$$

but from (1)

$$y^2 = \frac{2\,T}{w}\,x,$$

$$\therefore\ 4\,A = \frac{2\,T}{w},$$

The curve is, therefore, a parabola, the equation to which is

$$Y^2 = \frac{2\,T}{w}\,x.$$

Again, if it is desired to find the distance from the origin O of the parabola to the tangent K, where the curve will join a straight line K L, let the inclination of the line be expressed as the tangent of the angle K L N, that is, the vertical height divided by the horizontal distance—e. g. 1 in 5 = $\cdot 20$, 1 in 3 = $\cdot\dot{3}$.

Then

$$\tan K\,O\,N = \frac{\tan K\,L\,N}{2}$$

$$\frac{x_1}{y_1} = \frac{\tan K\,L\,N}{2},$$

but

$$x_1 = \frac{y_1^{\,2}}{4\,A},$$

therefore

$$y_1 = \frac{4\,A \times \tan K\,L\,N}{2},$$

and

$$4\,A = \frac{2\,T}{w}. \qquad (2)$$

$$\therefore\ O\,N = y^1 = \frac{T \times \tan K\,L\,N}{w}. \qquad (3)$$

Endless Chains—continued.

Again, to find the tension, in another place referred to as carrying tension, which must be applied in order that the chain may not trail on the ground:

$$x = \frac{w\,y^2}{2\,T} \qquad (1)$$

$$\therefore\ T = \frac{w\,y^2}{2\,x}. \qquad (4)$$

Of course, x must be a less distance than the height of the point of support on the hutch above the ground.

For an output of 700 hutches per day, the following oncost would be required to keep the chain going, viz.:—One man at the top, hanging on loaded hutches; one boy at the top, attending to the brake; one boy at the bottom, hanging on empty hutches; while the expense of upkeep of the incline would not be nearly so great as in an ordinary incline worked by a rope, owing to the speed being so low. To reduce the cost of attendance as much as possible, the inclinations should be arranged so that the empty hutches arriving at the top will detach themselves and run forward into the lye, for further transit by horses or drawers; while the full hutches will detach themselves at the bottom end and run forward to the pit-bottomer, or into a lye if the foot of the incline is not near the pit-bottom. When the output is small, so as to allow of the chain going at a slow speed, the brakesman may be dispensed with, the bencher being able to hang on and look after the brake as well.

The flattest inclination at which an incline of this kind will self-act depends on the comparative weights of full and empty hutches, on the weight of the chain, and on the friction of the hutches and chain wheels. As the chain should not touch the ground, there is no friction due to it, except that at the chain wheels, and the extra friction which its weight causes on the hutch wheels.

If W denotes weight of full hutches and chain on full side.
„ w „ „ empty „ „ empty side.
„ F „ friction of hutches, chain, and wheels on full side.
„ f „ „ „ „ empty side.
„ I „ tangent of angle of inclination, or inclination expressed as a fraction—i. e. for 1 in 60—$I = \frac{1}{60}$.

Then, before the incline will self-act,

$$(W \times I) - F \text{ must be greater than } (w \times I) + F$$

$$(W - w)\,I > F + f$$

$$I > \frac{F + f}{W - w}.$$

The inclination found from the above formula would be that on

Endless Chains—continued.
which the surplus power of the full side would just balance all the resistances, so that the incline would require to be steeper than this in order that it might self-act.

The friction would require to be assumed or found by experiment, while the proper size of chain may be found from the formula,

$$D = 3\sqrt{\text{breaking strain in tons}}\text{; or}$$

$$D = 3\sqrt{\text{working load} \times S},$$

D being the diameter of chain in sixteenths of an inch, and S being the factor of safety, which should be at least 5.

The working load on the chain is the greatest tension T, which is

$$T = (W \times 1) - F + \text{carrying tension.}$$

The chain should not be short-linked, as the chain-plate becomes fixed between the links of a short-linked chain, and tends to prevent the hutches from detaching automatically.

In an ordinary self-acting incline the road must be more or less uniform in gradient, for if steeper in some parts than in others the train must be run over the steep portion with great velocity in order that it may acquire sufficient momentum to carry it through the flatter portion; while in a great many cases it is impossible to work an incline by trams at all if the flat portion of the road happens to be at the top and the steep portion at the bottom, as a start cannot be obtained.

In working with a self-acting endless chain, if the average inclination of the road is not less than I, as found fr m the formula, the incline will work no matter how undulating it is, provided the average inclination is calculated from the total length of the road, and not from the horizontal distance on the section. The surplus power on a steep mine may be utilised for the purpose of drawing from a dook or level, not necessarily in the same straight line, by fitting the top wheel with a long shaft and putting on it a second driving wheel, or clip pulley, or rope drum provided with a clutch. In the same way water may be pumped, or almost any description of work done, if the power be sufficient.

The advantages which a self-acting endless chain possesses over an ordinary incline may be summed up shortly as follow:—

(1) Small cost of upkeep of rolling stock, owing to slow speed causing few breakages. When a hutch goes off the road the chain stops.

(2) Regularity of delivery. The hutches arrive at the pit-bottom in such a manner that only very short lyes are required, and consequently the travel of the bottomers is diminished.

Endless Chains—continued.

(3) When the output exceeds 100 tons a day, and probably before it, it can be worked much cheaper than an ordinary self-acting incline.

(4) Length makes no difference in the output or cost further than the increased upkeep of the road, whereas the difficulties in the way of drawing with a "cousie" increase with the length.

(5) Much less expenditure is required in making benches, as no long trains require to be collected on the incline as in a cousie.

(6) The cost for chains is less than for ropes, as a good chain will last 12–18 years.

HAULING AND HOISTING: *Electrical Haulage.* (Tallis.)

The various losses in an economical installation should not exceed the figures in Table 81 to obtain 20 H.P. in the ropes of the two branches respectively.

Table 81.

	Per cent.	On H.P.	Loss in H.P.	Electric Loss H.P.	Mechanical Loss H.P.
1. Loss between steam-engine and terminals of generator, or in belting and generator	20	80	16	6·0	10·0
2. Loss in cable to No. 1 motor	10	64	6·4	6·4	..
3. Loss in No. 1 motor	10	27·95	2·8	2·8	..
4. Loss in gearing between No. 1 motor and rope	20	25	5·0	..	5·0
5. Loss in cable from No. 1 to No. 2 motor	6	29·65	1·7	1·7	..
6. Loss in No 2 motor	10	27·95	2·8	2·8	..
7. Loss in gearing between No. 2 motor and rope	20	25	5·0	..	5·0
Total loss	..	..	39·7	19·7	20·0

The summary of the losses being nearly 40 H.P., it would require a steam-engine of 80 H.P. on surface to provide 40 H.P. in the haulage-ropes underground, an efficiency of 50 per cent., which will compare favourably with any existing system under the same conditions. It is possible that this efficiency can be considerably increased, and probably will be; however, there should be no difficulty in getting engineers to guarantee the above efficiency.

HAULING AND HOISTING: *Electrical Haulage.* (Tallis.)

Approximate cost of plant for installation of two 30-H.P. electric motors, situate respectively at 2500 and 2000 yd. distant from the generating station on surface.

	£	s.	d.
Two single horizontal 15-in. cylinder engines, coupled, stroke 30 in., with 12 ft. fly-wheel to receive driving-belt, automatic governor, expansion gear, and side-feed lubricator to each cylinder	500	0	0
Driving belt, 16 in. diameter, leather	60	0	0
Dynamo to give 56,000 watts at 500 volts and 480 revs. per minute, current and potential indicators, cut-outs, switches, &c...	500	0	0
4000 yards sheathed cable, equivalent to 0·5 in. diameter, solid copper rod, consisting of 37 strands of tinned copper wire, covered with one lap of pure and two layers best vulcanising rubber-coated rubbered tape, and the whole vulcanised together, further served with jute and sheathed with 20 galvanised iron wires, 0·169 in. diameter, and finally coated with three coats compound and two reserve tapes; finished diameter 1·48 in. ..	1200	0	0
1020 yards sheathed cable, equivalent to ·317 in. diameter, solid copper rod, consisting of 19 strands tinned copper wire (insulation as above), sheathed with 20 galvanised iron wires 0·131 in. diameter, finally coated and taped; finished diameter 1·18 in.	180	0	0
Two 30-H.P. motors, at 420 revs. per minute, absorbing about 23,000 watts	600	0	0

Foundations, engine-houses, steam-pipes from boilers, labour, drums, gearing, and erection, extra.

HAULING AND HOISTING: *Electrical Haulage.* (Lebreton.)

At Zaukeroda experiments have been made to determine the efficiency of the system. As measured between the indicated power of the steam-engine driving the generator, and the useful work done by the locomotive, it is 30 per cent.; as measured between the power absorbed by the generator and the power absorbed by the motor, it is 46·6 per cent. The cost of working is given as: 11*s.* 9*d.* for 660 wagon-loads in 16 hours, to which must be added 8*s.* 1*d.* for interest and depreciation at the rate of 15 per cent., making a total of 19*s.* 10*d.*, or 0·36*d.* per wagon.

Table 82 shows the cost as compared with previous results for traction by horses and men:—

Table 82.

	Cost of Electrical Traction, including Depreciation.	Cost of Horse Traction.	Cost of Traction by Men.
	d.	*d.*	*d.*
For 660 wagons	0·36	0·45	0·74
	Reduced to ton-miles.		
" "	2·0	2·5	4·1

Table 83.—HAULING AND HOISTING: *Comparison of Haulage Systems.* (Schutz.)

		Rope on Drum at Aniche.	Trailing Cable at Saarbrucken.	High-Speed Endless Cable at Shire Oaks, Nottingham.	Low-Speed Endless Cable at Bridge Pit, Wigan.	Low-Speed Endless Cable at Meadow Colliery, Wigan.	Endless Chain at Saarbrucken.	Endless Chain at Mine, Hassard, Belgium.	Steam Locomotive at Donan.	Steam Locomotive at Cessous.	Compressed Air, Petau System.	Compressed Air, Mekarski System.	Electricity at Zaukeroda.
Cost of installation	£	1600	2300	750	2300	750	4000	5600	1600	1600	650	1000	800
Interest and depreciation per ton-mile	d.	1·38	0·26	0·28	0·37	0·40	0·79	0·23	0·42	0·15	0·80	0·32	0·45
Cost of working per ton-mile	d.	0·53	1·02	1·82	3·71	2·02	0·74	0·22	0·60	0 52	1·20	1·35	1·11
Total cost per ton-mile	d.	1·91	1·28	2·10	4·08	2·42	1·53	0·45	1·02	0·67	2·00	2·17	1·56
Daily ton-miles		93	708	200	491	145	429	1950	293	867	65	97	143
Distance traversed..	yd.	600	4110	920	2163	638	1920	3500	2530	5041	676	676	676
Speed	yd. per minute	330	220	220	40	33	123	100	151	220	100	100	172
Weight of locomotive	tons	..	..	..	..	..	..	..	4·4	8	2·7	2 3	1·6

The increased cost of ventilation of the mine, when a steam locomotive is used, is not taken into account.

Table 84.—HAULING AND HOISTING: *Comparison of Haulage Systems.* (Lebreton.)

System.	Tons drawn per Shift.	Length of Line.	Cost per Ton-mile.
		yards.	*d.*
Tail rope	480	2130	1·15
Endless rope	429	1050	1·25
Floating cable	403	850	0·83
Trailing "	325	1400	2·01
Cable in Cadzow Colliery, Hamilton ..	842	1310	1·33
Electrical	..	..	0·9

Table 85.—HAULING AND HOISTING: *Comparative cost of the various haulage systems reduced to a tonnage of* 400 *tons over a distance of* 2200 *yd., interest and depreciation at* 15 *per cent. on first cost being allowed for.* (Vogel.)

		d.	
1.	Self-acting chain	0·45	per ton-mile.
2.	Electrical locomotive	0·88	"
3.	Endless chain	1·31 to 1·46	"
4.	Various systems of traction by cables	1·66 " 2·00	"
5.	Horses	3·24	"

HAULING AND HOISTING: *Winding Engines.* (Haswell.)

With winding engines, for drawing coals, etc., out of a pit, where it is required to give a certain number of revolutions, it is necessary to have given diameter of drum and thickness of rope, which is flat made, and contrariwise.

To Compute Diameter of a Drum, where Flat Ropes are used and are wound one part over the other.

Rule.—Divide depth of pit in in. by product of number of revolutions and 3·1416, and from quotient subtract product of thickness of rope and number of revolutions; remainder is diameter in in.

Ex.—If an engine makes 20 revolutions, depth of pit being 600 ft. and rope 1 in., what should be diameter of drum?

$$\cdot 1 \times 20 = \frac{7200}{62 \cdot 832} - 20 = 94 \cdot 59 \text{ in.}$$

To Compute Diameter of Roll.

Rule.—To area of drum add area or edge surface of rope; then ascertain, by inspection in table of areas, or by calculation, diameter that gives this area, and it is the diameter of roll.

Winding Engines—continued.

Ex.—What is the diameter of roll in preceding example?

Area of $94 \cdot 59 = 7027 \cdot 2 + (\text{area of } \overline{7200 \times 1}) = 7200 = 14227 \cdot 2$, and $\sqrt{14227 \cdot 2 \div \cdot 7854} = 151 \cdot 85$ in.

Or, radius of drum is increased number of revolutions multiplied by thickness of rope; as $\frac{94 \cdot 59}{2} + \overline{20 \times 1} = 67 \cdot 295$ in.

To Compute Number of Revolutions.

Rule.—To area of drum add area of edge surface of rope; from diameter of the circle having that area subtract diameter of drum, and divide remainder by twice thickness of rope; quotient will give number of revolutions.

Ex.—Length of a rope is 2600 in., its thickness 1 in., and diameter of drum 20 in.; what is number of revolutions?

Area of $20 +$ area of rope $= 314 \cdot 16 + 2600 = 2914 \cdot 16$, diameter of which is $60 \cdot 91$, and $\frac{60 \cdot 91 - 20}{1 \times 2} = 20 \cdot 45$ revolutions.

Or, subtract diameter of drum from diameter of roll, and divide remainder by twice thickness of rope; as $60 \cdot 91 - 20 = 40 \cdot 91$, and $40 \cdot 91 \div \overline{1 \times 2} = 20 \cdot 45$ revolutions.

To Compute Point of Meeting of Ascending and Descending Buckets when two or more are used.

To Compute Point of Meeting of Buckets. Rule.—Divide sum of length of turns of rope by 2, and to quotient add length of last turn; divide sum by 2, multiply quotient by half number of revolutions, and product will give distance from centre of drum at which buckets will meet.

Note 1.—Meeting will always be below half depth of pit.

2.—At half number of revolutions buckets will meet.

Ex.—Diameter of a drum is 9 ft., thickness of rope 1 in.; and revolutions 20; what is depth of pit, and at what distance from top will buckets meet?

To Compute this Depth. Rule.—To diameter of drum add thickness of rope in ft. and ascertain its circumference; to diameter of drum add quotient of product of twice thickness of rope and number of revolutions less 1, divide by 12 for a diameter, and circumference of this diameter is length of last turn, also in ft.; add these two

Winding Engines—continued.

lengths together, multiply their sum by half number of revolutions, and product will give depth of pit.

$$9 + \text{thickness of rope} = 9 + \tfrac{1}{12} \text{ of } 1 = 9 \cdot 083,$$
$$\text{which} \times 3 \cdot 1416 = 28 \cdot 54 \text{ ft.} = \text{length of first turn.}$$

$$9 \cdot 0833 + \frac{1 \times 2 \times \overline{20 - 1}}{12} \times 3 \cdot 1416 = 38 \cdot 48 \text{ ft.} = \left\{ \begin{array}{l} \text{length of} \\ \text{last turn.} \end{array} \right.$$

$$\text{Then } 28 \cdot 54 + 38 \cdot 48 \times \frac{20}{2} = 67 \cdot 02 \times 10 = 670 \cdot 2 \text{ ft., depth of pit.}$$

Winding Engines with Flat Ropes coiled on Drum. (Molesworth.)

To find the place of meeting for ascending and descending skips:—

t = thickness of rope in inches.
n = number of revolutions of the drum.
x = the distance below half the depth of the pit at which the skips will meet in yd.
$x = \cdot 0218\, n^2\, t.$

To find the diameter of the winding barrel for flat ropes:—

P = Depth of pit in ft.
R = Number of revolutions of engine.
T = Thickness of rope (in.).
D = Diameter of winding barrel in ft.

$$D = \frac{12\,P - 3 \cdot 15\,R^2\,T}{37 \cdot 7\,R}.$$

Safe Load on Chains. (Molesworth.)

D = Diameter in eighths of an inch.
W = Safe load in tons.
$D = \sqrt{9\,W}.$
$W = \frac{D^2}{9} = 7 \cdot 111\, d^2$, where
d = Diameter of iron in inches.

Table 86.—*Working Load of Chains.* (Molesworth.)

Diam. in... ..	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
Load	·44	·70	1·0	1·36	1·78	2·25	2·78	3·36	4·0
Diam. in... ..	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$
Load	4·69	5·44	6·25	7·11	9	11·11	13·44	16·0	21·78

Table 87.—*Mule, Tailrope, and Electrical Haulage compared.* (Pocock.)

(*a*) *Mule Haulage.* First Cost.

	£
16 large mules at 35*l*. each	560
16 sets of harness at 4*l*.	64
	624

Interest, Depreciation, &c.

20 % depreciation on 560*l*...	112
6 % interest..	33
	145

Working Expenses for 260 days.

16 mules, harness, shoeing, feed, care, at 1*s*. 3*d*. per diem ..	260
8 drivers at 7*s*. per day	728
Total yearly expense	1133

Or, on 260,000 tons yearly, 1·045*d*. per ton.

(*b*) *Tailrope Haulage.* First Cost.

Pair of 14 × 20 in. engines, 150 rev. a minute	400
18,000 ft. of 1 in. steel rope	691
150 rollers, $8\frac{1}{2} \times 7\frac{3}{4}$ in.	137
100 sheaves 2 ft. diam., and 1 sheave 6 ft.	340
Cost of erection, &c.	200
Boilers	300
	2068

Interest, Depreciation, &c.

6 % on 2068*l*.	124
Engine, depreciation 10 %, repairs 5 %	60
Boilers „ „ „	45
Ropes, life 1 year	691
Sheaves, life 2 years	170
Rollers, life 1 year	137
	1227

Working Expenses for 260 days.

Engineer at 10*l*. a month	120
Boiler attendance	60
Trip rider, at 7*s*. a day	91
Oil and waste	60
Total yearly expense	1558

Or, on 260,000 tons yearly, 1·438*d*. per ton.

Table 87.—*continued.*

(*c*) *Electrical Haulage.* First Cost.

	£
Engine, generator, and motor	2500
Boiler	200
Wire, insulators, switches, &c.	260
Labour of erection	250
	3210

Interest, Depreciation, &c.

Interest, 6 % on 3210*l.*	192
Depreciation on moving parts, 10 % on 2700*l.*	270
Repairs on moving parts, 8 %	216
Depreciation on standing parts, 6 % on 510*l.*	31
Repairs on standing parts, 6 %	31
	740

Working Expenses for 260 days.

Engineer at surface, at 10*l.* a month	120
" on motor, at 8*s.* a day	104
Trip rider, at 5*s.* 4*d.* a day	70
Oil and waste	30
Sand	20
Total yearly expense	1081

Or, on 364,000 tons, 0·715*d.* per ton.

Table 88.—*Tests showing Extra Stress upon a Hoisting-Rope Due to a Few Inches of Slack Rope.* (Roberts.)

First Test.

	Strain in lb
No. 1, empty cage lifted gently	4,030
No. 2, " "	4,030
No. 1, with 2½ in. slack rope	5,600
No. 2, " 2½ " " "	5,600
No. 1, " 6 " " "	8,950
No. 2, " 6 " " "	8,950
No. 1, " 12 " " "	12,300
No. 2, " 12 " " "	12,300

Second Test.

Cage and four empty cars weighed by machine	6,375
No. 1, cage lifted gently	6,725
No. 2, " " "	6,725
No. 1, with 3 in. slack rope	11,200
No. 2, " 3 " " "	11,200
No. 1, " 6 " " "	12,250
No. 2, " 6 " " "	12,250
No. 1, " 12 " " "	15,675
No. 2, " 12 " " "	15,675

Table 88—*continued.*

Third Test.

	Strain in lb.
Cage and full cars weighed by machine	11,300
No. 1, cage lifted gently	11,300
No. 2, ,, ,, ,,	11,525
No. 1, with 3 in. slack rope	19,025
No. 2, ,, 3 ,, ,, ,,	19,025
No. 1, ,, 6 ,, ,, ,,	23,500
No. 2, ,, 6 ,, ,, ,,	25,750
No. 1, ,, 9 ,, ,, ,,	27,950
No. 2, ,, 9 ,, ,, ,,	25,750

Koepe System of Winding from Shafts (Hughes).

Koepe's system of winding consists in substituting for the ordinary cylindrical drum a grooved pulley round which the rope makes rather more than half a turn, and thence passes over the pit-head pulleys and down the two divisions of the shaft. The balance rope beneath the cage is not a peculiarity of the system, as it has been applied for a long time to winding-engines where ordinary cylindrical drums are used. Experiments on the Keope system have shown that with the rope passing only one-half turn round the driving-pulley, the co-efficient of adhesion between steel rope and wood rim is in practice 30 per cent., which admits of a great excess being placed on present ascending loads before any slip can occur. That no slip actually results in practice (under the *usual* working conditions) is shown by the fact that at Bestwood colliery the winding takes place at the upcast shaft which is cased in, and the cages are entirely out of sight of the engineer, who has to rely entirely on the indicator, and under these circumstances has no difficulty in landing the load. It is, however, evident that when the cages reach the landing-places and rest on the stops (if any are used) the weight is removed from the rope, and sufficient adhesive power may not exist on the rim of the motive-pulley to enable the loads to be restarted. This can be guarded against by dispensing with stops altogether (as is done at the Sneyd colliery), or by continuing the rope past the cages by means of cross-heads above and below each cage, connected together by side pieces passing outside; the bridle chains are hung from the top cross-head, and when the cage rests on the tops the weight of the winding- and tail-ropes still remains on the motive-pulley. This is the arrangement used at Bestwood. The single winding-rope at the Hanover colliery has been found to last more than twice as long as the two ropes formerly adopted. The chief advantage of the system, apart from the perfect equalisation of the load, which can also be obtained in any engine with ordinary cylindrical drums, consists in doing away with the drum, which in many instances weighs 60 tons, and has of course to be set in rapid motion and stopped in a short space of

Koepe Winding—continued.
time, causing a large waste of energy. The Koepe system of winding has been adopted at Oberhausen and Westhausen in Westphalia, Stassfurth, in Upper Silesia, and Bestwood and Sneyd collieries in England, but has been abandoned at Oberhausen and Westhausen, possibly because breakage of one rope would cause the stoppage of both sides of the pit. After seven years' successful working, Koepe's system has been lately abandoned at Bestwood for two reasons: the management do not consider it safe, and slipping of the rope takes place every time it is oiled; this slipping commences immediately oil is applied, and after a time ceases altogether, to re-start, however, at the next oiling. This action is very objectionable at Bestwood, for, as before stated, the engineman has to rely entirely on the indicator for landing the cages, as he cannot see them when they reach the surface, owing to the top of the shaft being cased in. Against these abandonments we have the fact that no accident has occurred at the Hanover pit since the installation was put down in 1877; indeed, the life of winding-ropes is increased as before stated. The system is also giving every satisfaction at the Sneyd colliery in North Staffordshire.

HAULING AND HOISTING: *Hoisting in the Future* (Wheeler).

Theory indicates that tapered ropes have no limit in depth, and consequently that, by tapering and counterbalancing, ropes may be used in the deepest mines; but practically, in using flat ropes with reels, as now made, there is great risk of the rope slipping off the top coils and jamming down in the narrow V-space between the side of the reel and the coiled rope, with dangerous consequences, if the rope tapers to half its extreme width. By using a guide-sheave to wind the rope hard against one side of the reel, this danger may be overcome, though at the expense of more rapid wear of the rope, especially of the lacing. Flat ropes are now successfully and easily made of tapering section, and perhaps a better device can be used than the guide roller, to avoid jamming in the reel.

Round ropes are made tapering, and if the drum is grooved to properly receive the rope, it gives no trouble in winding like the flat rope. But American rope-makers do not advocate round tapering ropes, on account of the difficulty of manufacturing with perfect reliability.

If tapered ropes are ignored on account of their greater cost, and because of the objections of manufacturers, cylindrical ropes may still be used for unlimited depth by submitting to the low efficiency of the system when adopted at very deep shafts, necessitating a break of journey. While such a system of establishing interposed hoisting stations, with engines run by compressed air, whenever the rope becomes inconveniently long, can be carried on indefinitely, the outlay for plant becomes so great, the extra labour and time

In the Future—continued.

involved in changing cages at the intermediate levels are so expensive, and the efficiency of a compressor-plant is so low, with its consequent heavy fuel consumption, that the cost of installation and the operating expenses are enormous.

The simple, first-motion, cylindrical rope-hoist, constructed with the lastest improvements, possesses the advantages of a minimum cost of installation, the cheapest operating plant, and the greatest capacity of all known systems of hoisting. The following suggestions show where it may be improved.

(*a*) By Counterbalancing the Dead Load.—If the system is arranged duplex, or with a double-compartment shaft, the dead loads of the cage and cars counterbalance one another; and if the ropes are counterbalanced, which is perfectly effected by an under-rope, then there remains only the work of raising the coal or live load plus the small effort necessary to overcome the friction due to the dead load (rope, cage, cars). Hence only a moderate-sized engine is called for, instead of the large engines so frequently seen at deep mines.

(*b*) By Using a Smaller Factor of Safety for the Rope.—For hoisting ropes, the factor of safety should be made as low as possible, consistent with uncertainty in manufacture, abuse in use, sufficient margin to permit the reduction in section due to wear, and a working-strain safely below the limit of elasticity. The larger the factor of safety used, the greater is the section of the rope for a given load. This increases the dead load due to the rope's own weight, which even if counterbalanced augments the mass to be put in motion each trip, with the consequent strain in starting. The increased size of the rope decreases its life, as the greater the diameter, other things being equal, the more severe are the bending strains and the quicker the rope destroys itself. The factor of safety usually taken for steel ropes is 7, with 5 as a minimum and 10 as a maximum. For standard practice I would advise 4, provided—that the diameter of the sheaves and drums be *at least* 100 times the diameter of the rope for slow hoisting, and *at least* 150 times for fast hoisting; that a spring be interposed between the cage and the rope-capping, to ease the sudden strain in starting; that the rope be kept properly oiled; and that the rope be inspected daily for its entire length, for careful observation of the condition of the wires and prompt rejection of the rope when a certain number are broken.

Lagging the sheave with wood, having the engine set far enough from the shaft to avoid side-thrust and consequent lateral wear of the rope at the sheave and drum (carrying the rope on wooden rollers from the sheave to the engine if necessary), and carefully maintaining the entire hoisting-plant in proper alignment, will prolong the life of the rope in spite of the smaller factor of safety; and thus the safe working-length of a $1\frac{1}{8}$ in. cast-steel rope, when sustaining a 3-ton cage-load, may be increased from 3000 to 7500 ft.

In the Future—continued.

By decreasing the speed of hoisting, the wear of a wire rope is diminished; but this necessitates increasing the load to maintain a given output in the same time. Aside from the other disadvantages of excessive load, the maximum size of the cars used is frequently fixed by conditions that it is not economical to change in order to use large cars. Hence the more rapid wearing out of the ropes due to high speed in deep hoisting is willingly tolerated, in order to secure the capacity and economy due to fast hoisting; and the tendency of the times is to use larger and more powerful engines in order to obtain higher speeds as the mines become deeper; so that this method of prolonging the life of a rope is not in favour at present.

(*c*) By Use of Best Material for the Rope.—Very soft steel ropes possess the greatest flexibility, but they are deficient in strength, as the material has a breaking-strength of only about 60,000 lb. to the sq. in. The best grade of plough-steel, on the contrary, has a strength of 300,000 lb. per sq. in., but does not always give satisfaction as used with sheaves only 50–100 times the diameter of the rope, since the wires break too readily under such sharp bending. But if used with sheaves and drums 150–200 times the diameter of the rope, and if the wires are laid at an easy pitch with the "Lang lay," no such trouble should arise. With such a high-grade plough-steel rope of $1\frac{1}{8}$ in. diam., the safe working-length, using a factor of safety of 4, would now be about 30,000 ft., or 12,500 ft., with 10 as the factor of safety. The very low specific gravity of aluminium, 2·6, which is about one-third of that of steel, and its great strength, make it an ideal metal for a deep-hoisting rope, where a minimum of weight and a maximum of strength are demanded. If this metal or its alloys should prove to have the requisite flexibility, toughness, and strength, to make a reliable, durable hoisting-rope, the question of deep-hoisting with only cylindrical ropes is again settled beyond all cavil.

(*d*) By Designing the Cage with a Minimum of Weight.—As mines get deeper, economy demands the use of 3- or 4-, or even 6-deck cages. The prevalent objection to multiple-deck cages is the time required in decking, even if the decking is carried on simultaneously from two landings or levels. To deck from more than two or at most three landings or levels at once makes the stations very complicated underground, and is not desirable, even should the surface-plant be so arranged that there is no objection to having the ore or coal coming off on two or three levels. But with facilities for accommodating both loaded and empty cars at the landings, with sufficient help to quickly handle the cars, there is nothing to prevent loading and unloading a 6-deck cage in 30 seconds, or 5 seconds per deck. A multiple-deck cage, with only one car on a deck, can be designed of steel, with a very light, and yet stiff strong frame, in which the ratio of the cage-weight to that of its contents is very low.

Safety Cages.

The safety of the miner does not depend only on the description of safety-cage used, but also on the care which is taken to keep it in order, the reliability of the springs, the evenness, strength, and size of the runners, and the condition generally of the shaft. Cages that have proved effective under the most severe trials, when in good order, have utterly failed when they have been neglected, or when the springs have been faulty.

The different varieties of safety-cages may be divided into five classes :—

1st. Those which have grippers acting on the sides of the skids or runners, and in which the weight of the cage keeps the grippers apart, whilst, if the rope breaks, they are made to grip the sides of the skids by means of springs.

2nd. Those where, on the rope breaking, two chisel-pointed grippers strike and enter the face of the skids.

3rd. Those that are furnished with arms that strike into the sides or ends of the shaft, and which, like the two former, are kept from acting by the weight of the cage, whilst, should the rope break, the arms are thrust out by springs.

4th. Those that have wedges or rollers acting on the sides of the skids or runners, and in which the weight of the falling cage forces the wedge or roller into contact with the skids, and so stops the cage should the rope break.

5th. Those that are independent of the weight of the cage and act by specific gravity.

The test usually given to safety-cages has been by severing the connection between the cage and the rope at the shackle immediately above the cage. But a more severe test should be applied, to allow for the influence that the backdrag of the rope between the winding-gear and the pulley-wheel would have, in case the rope should break at the winding-gear, somewhat as follows :—A clamp is fixed to the winding-rope, close to the drum, and, by means of chains, securely fastened to a bar or timber near the drum. The winding-rope is then slackened for several feet, and so placed that it can run freely. By means of a slip-hook, the clamped rope is then suddenly liberated, and the result is noted. This test should be made at the surface with an empty cage and an empty or full truck on, and at a convenient level at some distance below the surface, also with an empty cage and an empty or full truck on the cage. With this test it will be found that some cages will fail altogether, some will fail on the surface, but will act well a certain distance down the shaft (owing to the back-drag between the pulley and the drum being counterbalanced by the weight of the rope down the shaft).

In addition to the safety appliances brought into action when the rope breaks, several cages are fitted with a hand-lever, by which the cage can be stopped by the miners themselves whilst in the

Safety Cages—continued.
cage. In some cases the hand-lever is attached to the main safety appliances, whilst in others it is independent of them, and is an additional safety-appliance actuated by hand. This is a desirable adjunct to a safety-cage, and may be the means of saving life when the cage is being lowered into water, gas, or foul air. The hand appliance separate from the main safety appliance is preferable to that connected with it, both because it forms an additional holding power, and also because it takes up less room in the cage, whilst equally efficient.

The grippers, which form a very important part of safety appliances, are of many different shapes or designs, as (*a*) chisel-pointed and cutting into the runners, (*b*) with serrated or embossed sides that present considerable holding surface to the skids, (*c*) with several teeth that by an eccentric motion claw the runners, (*d*) a gripper on one side only, whilst an iron check-plate is fixed to the other side, the skid being firmly held between the gripper and check-plate when the appliance is in action. The chisel-pointed gripper is quickest in action and least liable to slip, and one gripper with a check-plate on the other side is in some cases preferable to a gripper on each side.

The shoes of the cage should fit the skids or runners, to admit of the grippers being set in their proper position. It is well to make the shoes large enough to enable steel liners to be fitted into them, which can easily be renewed when worn.

The springs upon which depend the action of the safety appliances are of numerous designs—(*a*) spiral, (*b*) flat and like a coach or buggy spring, (*c*) with a sprial band, (*d*) of rubber in a state of tension, (*e*) with a block of rubber compressed. Where one spring alone is used, the flat or coach spring gives very good results; but where four spiral springs acting directly one to each gripper are used, the results are equally good. Rubber springs in tension have not proved equal to steel springs. In some instances the springs are confined in a square case so that they are not visible; but where possible they should be exposed to view, so that their condition can be easily seen and readily tested. Where the winding is very rapid, there is a severe strain upon the springs, both from the shock of the cage coming to the bottom, and also from the sudden pull when the cage is lifted with a load, the work being too rapid to allow of its being done gently. As many as 800 cage loads are brought up in a shift of 8 hours, and from the consequent strain on the springs the latter have to be renewed very frequently. The springs should be sufficiently strong and in good order, and should be close up to the work, so that the safety appliances act instantaneously. It must, however, be borne in mind that if the springs be too finely set, the appliances are liable to act when not required, in quick winding or from the oscillation of the rope, which is a source of danger; and managers should be careful to ascertain that the springs are at the correct point of

Safety Cages—continued.

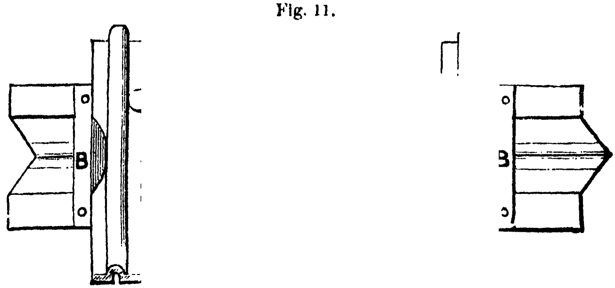
tension so that they will neither cause the cage to catch in the shaft nor fail to make the safety appliances act instantaneously in case of the rope breaking.

Safety-hooks, although not forming part of the safety-cages, are intimately connected with them. A great number of accidents have been averted by their use.

Permanent Way.

An improved system of chairs and sleepers has lately been brought out by the Chair and Sleeper Company (Limited), Widnes, Lancashire.* In Fig. 11, A is a spring clip riveted to the sleeper,

Fig. 11.



Improved System of Chairs and Sleepers.

and is hammered round on to flange of rail to fasten it. Two of these spring clips are used for joint sleepers. B is a fixed clip, but for light pit rails a small spring clip is riveted to one side of the sleeper only. For ordinary tram rails, for which all the advantages of a fished joint without any of its disadvantages are claimed, a method is adopted in which the ordinary back-clip of the sleeper is widened and lengthened out till it assumes the dimensions of an ordinary fishplate. This is riveted to the sleeper, and has suitable studs projecting on it, which engage into the ordinary fishholes of the rail when it is placed on the sleeper. The steel spring clip, which is made of the best steel, and riveted to the sleeper on a washer, so that it can revolve, is then hammered round, until the end of it mounts the flange of the rail—one corner, only, of the clip being turned up, to give it a start on the flange. A great strain is thus put upon the clip, and it is somewhat lifted. This strain, combined with the elasticity of the steel, is so adjusted to the different sections of rails as to take up any wear there may be on the rail; thus always forming a tight fastening, and holding up the rail against the back fishplate, which thus takes all the outward thrust of the railway wheels. The steel revolving clips have

* The same firm have many other improvements in rails, sleepers, and fastenings.

Permanent Way—continued.
square corners, which spring up against the web of the rail, and thus prevent them from turning round or working loose. By this means, it will be seen, the rails are not only fastened to each other, but also at the same time to the sleeper, a great advantage, especially on inclines. The saving is apparent when it is stated that nothing but a hammer is required to lay a railway by this system, and consequently any unskilled labour can be used.

Aerial Wire Rope Tramways.

Aerial wire rope lines are specially suited for mining purposes, and besides being used for the transporting of ore, coal, slag, &c., are now being adopted for the carriage for all kinds of goods where an ordinary railway cannot well be employed.

By means of these lines the steepest gradients can be surmounted, and rivers, buildings, &c., easily passed over. Loading and unloading can go on during all weathers, as the working of the line is not interfered with by rain or snow. Comparatively inexpensive foundations are required, and the number of men employed is reduced to a minimum.

Aerial lines cannot be worked satisfactorily round *curves*, care should therefore be taken when setting out one of these lines to have the loading and unloading stations so situated that the ropeway can be carried in a straight line from one to the other. If this is not possible, one or more so-called angle stations must be employed; these, however, increase the cost of working, and should be avoided unless absolutely necessary.

There are two systems of aerial lines, the single rope and the double rope.

The single rope lines have an endless running rope, which at the same time does duty for carrying and hauling the buckets. The buckets are either rigidly attached to the rope, or are suspended by means of a saddle which grips the rope by friction. These lines are cheaper and simpler than the double-rope ones, and are suitable for light loads and easy gradients.

The double rope or "Otto" system employs an independent heavy fixed rope for carrying, and a light running rope for hauling the buckets. The usual loads for the single lines are 2–3 cwt., for the double lines 5–8 cwt., in special cases, up to 10 and even 20 cwt. can be carried. The steepest gradients can be worked with safety by the double lines; the buckets are attached to the hauling rope by means of special grips, and travel at about 300 ft. per minute. The double lines are capable of transporting 60–80 tons of ore per hour, and of working over very long distances.

The supports are either of wood or iron, and are usually two-legged, four-legged supports only being employed at points where the strains are very great.

Spans up to 1500 ft. where necessary can be adopted; but such

Aerial Tramways—continued.

very large spans are not recommended, unless the section of the ground absolutely requires it. For fairly even country, the supports are generally placed 100–200 ft. apart, according to the quantity of material to be transported.

The following particulars of Otto's double rope system have been furnished by Commans & Co., 52, Gracechurch Street, London, E.C. :—

Ordinary wooden supports cost 45*l.* a piece; iron ones 8–10*l.*; high standards proportionately more.

The carrying ropes have usually a diameter of $1–1\frac{1}{2}$ in. for the loaded rope, and $\frac{3}{4}–\frac{7}{8}$ in for the unloaded; the hauling rope has a diameter of $\frac{3}{8}–\frac{3}{4}$ in., according to the length of line and the quantity that has to be transported. It is not advisable to make the section of a line more than $3–3\frac{1}{2}$ miles long.

The power required for driving these ropeways is very small.

The cost of ropeways of course varies very considerably, according to the quantity of the material to be transported, and the nature of the country to be crossed. The ironwork for a line, including ropes, buckets, and terminal gear complete, but exclusive of supports and erection, would cost approximately 1000*l.*–1500*l.* per mile for the single rope system, and 1200*l.*–2000*l.* per mile, for the double rope system, according to the quantity carried.

The cost of erection depends so much on the part of the world in which the line is to be employed, and the cost there of labour and material, that it is impossible to give anything like a reliable figure for this.

The subjoined particulars, furnished by Bullivant & Co., 72, Mark Lane, London, E.C., will enable the reader to form an idea of the cost of any tramway he may contemplate erecting, but as the price varies greatly according to the ground passed over and the material to be transported, it must be borne in mind that the amounts given are purely approximate.

	50 Ton per 10 hours Line.	100 Ton per 10 hours Line.	200 Ton per 10 hours Line.
	£	£	£
1. Rope, pulleys, and rolling stock for a length not exceeding one mile .. .. per mile	310	460	580
2. Driving and tightening gears with shunt rails for a tramway, one mile or less in length	60	130	170
3. Rope, pulleys, and rolling stock for a length not exceeding 3 miles, but over one mile, per mile	340	490	620
4. Driving and tightening gears with shunt rails for a tramway not exceeding 3 miles in length, but over one mile	120	250	300
5. Angles, giving any degree of deviation.. ..each	25	35	45
6. Packing, &c... .. .. about	20 to 30	30 to 40	40 to 50

Aerial Tramways—continued.

To which must be added the cost of wood posts, and engine power. The former average about 30 per mile, and on level ground are about 15 ft. high, costing 4*l.* to 5*l.* each—irregularities of level will cause a corresponding variation in the heights of the posts.

The amount of engine power varies under all circumstances.

The wood frames for carrying terminal gears and shunts rails are not included in above prices.

The prices above will usually be found to be rather in excess of a final estimate made on receipt of full particulars.

Tramways for lengths under half a mile should be specially estimated for.

To illustrate the proper method of estimating from above prices, the following examples are given, viz.:—

1. Cost required for a tramway ¾ mile long to carry 50 tons per 10 hours with one angle.

Rope, pulleys, and rolling stock as per No. 1, 310*l.* per mile, or for ¾ mile 232*l.* 10*s.*, and terminal gear, &c., as per No. 3, 60*l.*, and with curve as per No. 5, 25*l.* Total cost, 317*l.* 10*s.*

2. Cost required of a tramway 2 miles long to carry 100 tons per 10 hours as per No. 2.

Rope, pulleys and rolling stock will cost 980*l.*, and, as per No. 4, driving gear, &c., will cost 250*l.* Total 1230*l.*

Packing is only necessary for export.

WATER SOFTENING.

Water is generally described as being soft or hard. It is called hard when it contains considerable quanties of the salts of calcium and magnesium in solution, but when only a small quantity of these salts is present it is called soft. The chlorides, sulphates, and nitrates of calcium and magnesium are easily dissolved and maintained in solution by water, but the carbonates of these elements can only be maintained in solution by an excess of carbonic acid in the form of bi-carbonates.

The following distinctions are made with regard to hard waters:—

(1) Temporary hardness, that is, hardness caused by the bi-carbonates of the alkaline earths, and which disappears in boiling.

(2) Permanent hardness, that is, hardness caused by the chlorides, sulphates, and nitrates of the alkaline earths, which is not lessened by boiling. The sum of the temporary and permanent hardness is the total or aggregate hardness.

In order to express the relative hardness of different waters, the following measurements have been adopted:—

England	..	1 grain of calcium carbonate ($CaCO_3$) per gallon of water.
France	..	10 milligrams of calcium carbonate ($CaCO_3$) per litre of water.
Germany	..	10 milligrams of calcium oxide (CaO) per litre water.

Calcium, in the form of bi-carbonates and sulphates, is the chief constituent of the dissolved mineral matter in hard water, whilst it occurs also in small quantities as chlorides, nitrates, and nitrites. Next in order comes magnesium in the same combination as calcium. The bi-carbonates of iron and manganese, and the carbonates, chlorides, sulphates, nitrates, and silicates of sodium and potassium, are rarely absent, but seldom occur in large quantities. Water also absorbs oxygen, nitrogen, and carbonic acid, and occasionally sulphuretted hydrogen may be found in it. Organic matter occurs in some lake and river waters. Carbonic acid enables water to dissolve substances, such as the carbonates of calcium, magnesium, iron, and manganese (which pure water could only dissolve with great difficulty in minute quantities if at all), by converting the carbonates into bi-carbonates, the bi-carbonates

Water Softening—continued.

being soluble in pure water. It has been found from experience that scale over the heating surfaces of a boiler to the thickness of $\frac{1}{16}$ in. will cause a waste of about an eighth of the efficiency of the boiler, and the waste increases as the square of the thickness. The amount of incrustation varies considerably with the quality of water, and with the regularity with which the operations of blowing through and cleaning out are practised. Occasionally vegetable matter of a glutinous nature, held in suspension by the feed water and precipitated by heat or concentration, covers the heating surface with a thin coating almost impermeable to heat, and which hardens the mineral deposit so that it is next to impossible to remove it, and hence causes overheating.

The Porter-Clark process is based on the following theory:—When ordinary burnt lime or calcium oxide is added to water which contains the bi-carbonates of lime or manganese, the excess of carbonic acid necessary to keep the lime or magnesia in solution in the form of a bi-carbonate combines with the calcium oxide, forming insoluble carbonate of lime, both by the decomposition of the bi-carbonate of lime and by the combination of the excess of carbonic acid given off in decomposition with calcium oxide added to the water.

In this reaction the carbonates only are precipitated. The sulphates are precipitated by using a small quantity of soda, Na_2CO_3. The sodium carbonate and calcium sulphate mutually exchange their acids, forming insoluble carbonate of lime and soluble sulphate of soda. The latter salt is so very soluble that it is not precipitated even after much concentration upon evaporation, and thus it flows out of the boiler when the mud-plugs are removed for washing-out.

A little alum is mixed with the soda to aid the precipitation of solid matter held in suspension by the water; it also materially assists the precipitation of the salts in the precipitating tanks.

The reaction is represented by the following equations:—

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.$$
$$H_2Ca\ (CO_3)_2 + CaO = 2\ CaCO_3 + H_2O.$$
$$H_2Mg\ (CO_3)_2 + CaO = CaCO_3 + MgCO_3 + H_2O.$$

The quantity of lime required to soften 1000 gal. of water is 2·24 lb.; soda, 4·5 lb.; and alum, 0·1 lb. The above quantities give very satisfactory results. It is not found necessary to reduce the degree of hardness lower than 6° and 7°, as the heating surfaces are kept practically clean when water of this degree of hardness is used. The water, after being softened, dislodges old incrustations and deposits from boilers previously using hard water. (W. W. F. Pullen, Proc. Inst. C.E., xcvii. 354.)

STAMP BATTERIES.

STAMP BATTERIES: *Gold.*

To find the horse-power required to drive a battery, multiply the weight of one stamp by the number of stamps in the battery by the height of lift in ft. by the number of lifts per minute; add one-third of the product to the result for friction, which will be the number of ft.-lb. per minute; divide this by 33,000, which is the number of ft.-lb. per minute equal to 1 H.P., and the result will be the H.P. required. For example, supposing a stamp weighs 800 lb., that there are 5 in a set, that each stamp has a lift of 9 in. = 0·75 ft., and gives 80 blows per minute, then :—$800 \times 5 \times 0 \cdot 75 \times 80 = 240{,}000$; one-third of 240,000 = 80,000; this added to 240,000 = 320,000; 320,000 divided by 33,000 = 9·7 H P., or 1·9 H.P. per stamp. The total weight of a battery, including mortar-box, stampers, &c., may be roughly estimated at 1 ton per stamp. Medium-sized stampers, i. e. stem, tappet, head, and shoe, weigh 600–700 lb., and require about ½ H.P. Heavy stampers weigh 800 lb. and over.

Table 89.—*Dimensions of Parts of Stamps.*

Name of Mill.	Length of Stem.	Diam. of Stem.	Weight of Stem	Height of Shoe.	Diam. of Shoe	Weight of Shoe.	Height of Boss.
	ft.	in.	lb.	in.	in.	lb	in.
Douglas	12½	2⅞	290	9	8	115	18
Cons., Virginia ..	13	3⅛	320	7	8	110	16
Lincoln	13	3⅛	320	7	8½	119	18
Brunswick	15	3⅛	375	10	9	125	18
Electric	11⅜	3	258	8	8⅛	123	16
Eureka	14	3½	450	..	..	160	..
Keystone	..	..	..	..	..	100	..
Stanford	..	..	..	..	..	120	..
Walhalla	10¾	3⅜	..	9	10	..	14

Name of Mill.	Diam. of Boss.	Height of Tappet.	Diam. of Tappet.	Weight of Tappet.	Height of Die.	Diam. of Die.	Weight of Die.
	in.	in.	in.	lb.	in.	in.	lb.
Douglas	8	12	8	120	..	..	..
Cons., Virginia ..	8	10	7½	95	..	..	..
Lincoln	8½	10	7¾	93	5¼	8½	99
Brunswick	8	12	9	125	..	..	..
Electric	8⅛	8½	7½	83	6	8⅛	100
Eureka	..	..	..	120	..	..	120
Keystone	..	..	..	100	..	..	113
Stanford	..	..	..	114	..	..	..
Walhalla	10	..	..	..	..	..	..

Table 90.—*Dimensions and Working Results of a number of Mills in various parts of the World.*

Mill or District.	Weight of Stamps.	Drops per Minute.	Depth of Drop.	Crushed per 24 Hours.	No. of Stamps.	Duty per Stamp.	H.P. per Stamp.	Holes per sq. in. of Grating.	Water per Stamp per 24 Hours.	Mercury used per Stamp.	Mercury lost per Stamp.
	lb.		in.	tons		tons			gal.	lb.	oz.
Grass Valley.. ..	850	61	10	40	20	2	..	..	..	..	..
"	700	68	10	32	20	1·12	..	..	..	..	..
Eureka	950	80	9	..	60	2½-3	..	..	..	..	..
Brunswick	..	..	..	160	56	3	..	..	..	..	..
Keystone	750	75-80	..	75-80	40	2	..	..	..	..	..
Idaho	950	80	9	..	..	..	..	..	..	..	..
Metacom	900	90	10	..	..	..	..	..	..	..	..
Port Philip	672	75	..	..	56	2·2	1	..	..	..	..
"	896	75	..	..	24	3	1¼	..	..	..	..
Nova Scotia	650	55	6 -9	..	..	1 -1½	..	..	..	..	..
	cwt.										
Ballarat	4 -8½	50-85	7 -10	..	..	1 -4	1 -2	40-200	950- 8,640	5-75	1 - 8
Beechworth	4¼-7¼	40-90	5 -14	..	..	⅘-4	¾-1½	60-140	720-11,520	5-70	½- 8
Sandhurst	5 -8	25-75	6 -18	..	..	1 -3¾	⅘-2	64-140	4,000- 8,640	10-40	½- 5½
Maryborough ..	4½-8	50-75	6 -22	..	..	1 -3	½-2½	70-144	900- 8,640	3-30	1¾- 8
Castlemaine	4½-8	35-75	6 -15	..	..	1 -3¼	½-2	40-144	4,800-12,960	6-40	¼-24
Ararat	5 -6¾	60-72	7½-10	..	..	1¼-1½	¾	90-120	4,320-12,960	6-47	½- 7
Gippsland	6 -7½	60-80	7 -10	..	..	1½-2	¾-1½	70-250	1,600-25,000	10-37	⅕-32

Gold Batteries—continued.

Life of Battery.—The duration of the several parts of a stamp battery is very unequal. An ordinary die should last about twice as long as the shoe, or say six weeks to two months; the rate of wear is commonly $\frac{1}{2}$–1 lb. per ton of ore treated. The conditions which govern the rate of wear are the speed of the battery, regularity of feeding, hardness of ore, and quality of iron. Good cast iron is as enduring as steel, but much of the cast iron employed for this purpose in remote localities is far from good. Shoes generally last 4–6 weeks, wearing at the rate of $\frac{1}{2}$–$1\frac{1}{2}$ lb. per ton of ore put through.

Stamp stems, especially when running in wooden guides, should last 3 or 4 years, and, with regular feeding, very much longer; the jar occasioned by a short supply of ore in the mortar is apt to cause them to break off at the ends. When this happens, the injury is remedied by welding on a piece, which may be done repeatedly. Stamp heads sometimes split when not bound with iron rings, and the sockets become enlarged by wear; but the latter drawback may be overcome by inserting wooden or iron wedges. Tappets should endure 4 or 5 years, but are sometimes split through wedging up too tightly.

Table 91.—*Gauges of Screens.*

No. of Needle.	Mesh.	Width of Slot.
		in.
1	12	$\frac{58}{1000}$
2	14	$\frac{49}{1000}$
3	16	$\frac{42}{1000}$
4	18	$\frac{35}{1000}$
5	20	$\frac{29}{1000}$
6	25	$\frac{27}{1000}$
7	30	$\frac{24}{1000}$
8	35	$\frac{22}{1000}$
9	40	$\frac{20}{1000}$
10	50	$\frac{18}{1000}$
11	55	$\frac{33}{2000}$
12	60	$\frac{15}{1000}$

CRUSHING ROLLS.

Table 92.—CRUSHING ROLLS: *Dimensions and Product at various Mines.*

Name of Mine.	Rolls.				Total Pressure on Rolls.	Sifter.				Diameter of Raff-Wheel.	Horse-power.	Quantity Crushed in 10 Hours.	Cost of Crushing per ton.
	Diameter.	Length.	Revolutions per Minute.	Crushing Area per Minute.		Diameter.	Length.	No. of Holes.	Revolutions per Minute.				
	in.	in.		sq. in.	cwt.	in.	in.	sq. in.		ft.		tons.	d.
Grassington Mines.. ..	27	12	$5\frac{1}{2}$	5,593	91	21	48	$6\frac{1}{4}$	37	14	..	80	..
Minera	14	14	8	4,920	$73\frac{1}{3}$	24	42	9	48	10	6	20	$2\frac{1}{2}$
Cwmystwith, No. 1 ..	27	14	4	4,748	78	20	33	9	24	16	..	32	$2\frac{1}{2}$
Cwmystwith, No. 2 ..	27	14	$4\frac{1}{2}$	5,341	85	24	36	9	24	16	..	35	$2\frac{1}{2}$
Goginan	30	14	$5\frac{1}{2}$	7,254	39	20	39	9	36	16	..	30	$2\frac{3}{4}$
Cwm Erfin	27	14	$7\frac{1}{2}$	8,902	293	26	32	9	30	16	..	20	3
Lisburne, No. 1	27	15	6	7,632	180	22	36	$12\frac{1}{4}$	30	16	..	42	$2\frac{1}{2}$
Lisburne, No. 2	27	15	6	7,632	224	22	36	$12\frac{1}{4}$	30	16	..	42	$2\frac{1}{2}$
Derwent	27	14	7	8,309	227	22	60	16	..	15	..	60	$2\frac{3}{4}$
Goldscope	14	18	14	11,060	6	..	..	..	..	..	..	25	$2\frac{1}{2}$
East Darren	30	18	6	9,996	207	24	36	16	45	16	..	25	$2\frac{3}{4}$
Cefn Cwm Brwyno ..	20	13	5	4,080	84	20	48	16	$27\frac{1}{2}$	11	..	20	$2\frac{1}{2}$
Lisburne, No. 3	18	16	8	6,432	169	22	36	25	30	16	..	42	$2\frac{1}{2}$
Llandudno	18	15	15	12,705	61	..	..	..	..	..	..	30	..
Wheal Friendship.. ..	23	12	10	8,670	123	24	36	36	30	13	13	20	$11\frac{1}{3}$
Pontgibaud	25	12	$12\frac{1}{2}$	12,075	36	22	44	36	60	15	15	17	$2\frac{1}{2}$
Devon Great Consols ..	34	22	7	16,443	458	24	84	64	21	..	..	65	$3\frac{3}{4}$

Jordan's Patent "Centrifugal" Process.

One set of plant comprising this process consists of the following:—

One ordinary "Blake" stone-breaker.
,, Jordan's patent fine reducer.
,, ,, ,, amalgamator.

This set is equal in capacity to 10 heads of Californian gravitation stamps, if placed on the same basis as to nature of quartz and fineness of grinding.

The process is complete in itself, the amalgamator taking the place of copper table, pan amalgamators, blanket strakes, and all other appliances. It is capable of treating the most refractory ores and of saving 85 to 95 per cent. of the gold contained, whilst practically the whole of the precious metal is extracted from free-milling ores.

The amalgamators are also often used in front of ordinary stamp batteries, especially where fine or float gold is concerned, which they are found very efficacious in catching.

The following table of comparisons between the process and the ordinary stamp battery will probably be useful:—

A. *Jordan's Patent Plant.* B. *Stamp Battery.*

	Cost of Plant.	Weight of Plant.	Freight at £15 per ton.	Cost of Erection on a moderate site.	Time occupied in Erection.
A	£800	15 tons.	£225	£50	2 to 3 weeks.
B	£1,399	51½ tons.	£772	say £275	2 to 3 months.
	Power required to Drive Plant.	**Cost for Treatment per ton of Ore.**	**Cost of complete Plant Erected, say, in Transvaal, without Power.**	**Labour for Double Shift.**	**Cost of Wear and Tear and Renewals per annum.**
A	8 to 10 H.P.	5*s.* to 10*s.*	£1,075	2 skilled mechanics, 2 labourers.	£50
B	15 to 20 H.P.	12*s.* to 18*s.*	£2,416	4 skilled mechanics, 6 labourers.	£150 to £200

Table 93.—*Cost of Jordan's Centrifugal Plant.*

	£
One patent stone-breaker	100
" " centrifugal fine reducer	250
" " " amalgamator	250
The necessary shafting, pulleys, bearings, couplings, gear, belting, and laces for driving, and the necessary pipes, cocks, and connections for the immediate water supply	200
One set complete ready for working	800
A suitable steam engine for driving one set of the plant of high pressure horizontal type, having cylinder 10 in. diam. and 18 in. stroke, feed pump and high speed governor and throttle valve complete. The engine of high-class workmanship and very best material	154
A single-flued multitubular steel boiler 11 ft. long by 5 ft. diam., with all the necessary mountings, and fitted with smoke-box jacketed to act as feed-water heater, and 20 ft. wrought iron chimney 2 ft. diam. The whole arranged so as to require no brick setting or flues	255
Steam and blow-off pipes, cocks and connections between engine and boiler, supposing the same to be in close proximity	20
Engine and boiler complete as above	429
Process complete with engine and boiler and all accessories as above	1229

From 5 to 10 per cent. should be added to the above prices for packing for shipment, and delivery F.O.B. English port.

RIVER MINING.

RIVER MINING: *Ball Dredger.* (Langley.)

The fan makes 350 revolutions per minute, and at that speed is capable of raising 400 tons of sand, gravel, and stones per hour, but the average in actual work may be taken at 200 tons per hour. This is with a 10 h.p. engine, and working in a depth of water varying from 7 to 25 ft.

Table 94.—*Cost of Dredging.*

Cost of dredger, say		2000*l.*
Nominal horse-power		10 H.P.
Depth at which it excavates		25 ft.
Quantity it excavates per annum		200,000 tons.
Labour for dredging, lead (2 miles) and discharging	per ton	2·125*d.*
Coal and other stores	„	0·375*d.*
Repairs (total £60)	„	0·072*d.*
Total working cost	„	2·572*d.*
Add 10 per cent. interest on capital	„	0·240*d.*
Total cost per ton, including interest on capital	„	2·812*d.*

This cost may be taken to be about 1¼*d.* for dredging, and the balance for the towage of lighters and discharging at sea.

The consumption of coal is about 1 ton per 1000 tons of sand dredged.

ORE DRESSING.

ORE DRESSING: *Conditions.*

The object of dressing ores is to separate the useful from the useless portions, and to sort the valuable minerals from each other. It should be carried out as near the mine as possible, to avoid carriage of worthless material. Water is essential, and the floors should be arranged so that the matters can be moved forward in a measure by their own specific gravity.

The specific gravity of minerals commonly met with in wet dressing floors is as follows:—

Gold	[illegible]	Stibnite	[illegible]
Mercury	10·6	Barytes	4·3–4·7
Silver	10·5	Copper pyrites	4·1–4·3
Copper	8·4–9	Zincblende	4·1
Iron	7·5	Chalybite	3·6–3·9
Galena	7·5	Calamine	3·3–3·6
Cassiterite	6·4–7·1	Fluorspar	3·1
Cinnabar	6·7–8·2	Calcite	2·6–3·0
Mispickel	6·0–6·2	Felspar	2·5–2·9
Proustite	5·5	Quartz	2·5–2·7
Iron pyrites	4·8–5·2	Gypsum	2·2–2·4
Fahlerz	5·0–5·1	Coal	1·2–1·5
Purple copper ore	4·9–5·1	Lignite	1·2–1·4
Magnetite	4·8–5·2		

Decomposed silver and other ores are difficult to dress, especially if easily powdered, *e.g.* malachite, argentiferous cerussite, cinnabar, and spangles of native silver. It is difficult to separate zincblende, copper pyrites, iron pyrites, mispickel, and barytes from silver ores; wolfram from tin ores; chlorite and epidote from copper ores; and chalybite from copper pyrites and galena.

The following minerals are affected by the association of those in brackets:—

Hæmatite, limonite, and chalybite (iron and copper pyrites and apatite are injurious).

Cassiterite (iron pyrites, copper pyrites, mispickel, and zincblende are injurious; bismuth makes the colour dull; copper makes it brittle).

Lead (arsenic makes it brittle; antimony makes it hard; fluorspar promotes its fusibility; chalybite and barytes are also advantageous).

Zinc (lead spoils it).

Copper (lead must be separated from it if it is to be treated by precipitation process).

Conditions—continued.

Silver (lead and antimony are injurious for the amalgamation process; also talc for chlorination).

Cobalt (for blue paint calcspar, brownspar, manganese spar, hornstone, ferruginous quartz, and galena are injurious; nickel, when predominant, imparts a red tinge; arsenic intensifies the blue colour, and renders it more agreeable).

Magnetite (mica, lime, garnet, augite, and hornblende promote its fusibility).

Auriferous pyrites (for chlorination process, talc is injurious).

When pieces of different minerals of the same size are allowed to settle in water, the heavier particles fall first. When pieces of different minerals of the same weight are subjected to a flow of water sufficient to move them along, the specific lighter material, having a larger surface exposed, is washed away quickest.

Another condition, not less important than those just given, for good concentration of the different classified portions of material, is the proper regulation of the velocity of the throw. For the tables applied to the treatment of the two coarser sizes, it ought, in the average, not to exceed 1 ft. per second, whilst slime-tables require a velocity of stroke of only 0·5 ft. per second; a greater velocity causes the tables to slide, so to speak, from underneath the particles of ore, thus retarding their progress. The motive power required for working a double table is 0·26 h.p., and the working effect per hour of a single table is 55 lb. of slimes and 300 lb. of sands. Six continuously-acting double tables are capable of working in 24 hours 10–12½ tons of crushed material, classified by four pyramidal boxes. These figures refer only to Rittinger's tables.

ORE DRESSING: Table 95.—*Adjustments of Rittinger's Continuously-acting Side-throw Percussion-table.*

Description of Ores.	Inclination of the table. In the direction of the throw.	Inclination of the table. Towards the front.	Constant pressure of table against bumping-block.	Throw or stroke. Length.	Throw or stroke. Number of throws per minute.	Supply of material and cleaning water per minute upon a double table. Classified material. Supply in measurement.	Classified material. Weight.	Classified material. Solid contents carried by the water.	Cleaning water. Front cleaning water.	Cleaning water. Back cleaning water.
FOR AURIFEROUS LEAD ORES.	Lines.	Lines.	lb.	Lines.	No.	cub. ft.	lb.	lb.	cub. ft.	cub. ft.
Coarse sand, 1st classifier	..	84	140	24	73	0·392	23·51	2·665	1·023	1·251
Fine do. 2nd do.	6	58	110	21	85	0·333	20·09	1·763	1·093	1·234
Coarse slime, 3rd do.	7	56	106	18	100–105	0·323	18·94	0·914	0·888	0·977
Fine do. 4th do.	14	52	100	10	112–130	0·236	14·07	0·750	0·669	0·914
FOR SILVER ORES.										
Coarse sand, 1st classifier	6	72	212	18	76–78	0·420	26·64	4·956	0·711	1·187
Fine do. 2nd do.	6	54	183	12	86–88	0·405	24·80	3·410	0·256	0·677
Coarse and fine slimes .. } 3rd and 4th classifiers ..	6	30	100	10	100–110	0·261	16·55	3·580	0·313	0·708

Jigging. (H. S. Munroe.)

It is hardly necessary to dwell upon the importance of the jig. Within its proper sphere no substitute has been found that does the work as well or as cheaply. Its capacity is large, it requires but little attention, and the losses are small. In one form or another, it is the principle machine used in the concentration of low-grade ores, and for the separation of one metallic mineral from another; and it is almost the only machine used for the purification of coal. There are two recognised systems of jigging, the English and the Continental or German. The English system is a development of the hand-jigging formerly employed in Cornwall and other metalliferous districts of England. In this method the crushed ore, coarse and fine together, is first jigged on a hand-sieve with coarse mesh; and the fine stuff, somewhat concentrated by passing through the bed of coarse mineral grains on the sieve, is again jigged on a sieve of finer mesh. In the adaptation of the system to machine-jigging, many modifications of detail have been necessary. The general treatment, however, is the same, and includes a preliminary jigging on roughing-jigs, followed by a concentration of the hutchwork on finishing-jigs of finer mesh. In both roughing- and finishing-jigs, a bed of mineral is maintained on the sieve; and the concentration is mainly effected by jigging through this bed. The Continental or German system starts with a size-classification by screens, after which the different sizes are treated on separate jigs.

There are also combinations of the two systems. The use of a bed of mineral grains, and concentration by jigging through the sieve, has been adopted in Continental practice for fine jigging. At the Lake Superior dressing-works, a somewhat imperfect size-classification by water has been introduced as a preliminary to jigging. In the Continental dressing-works, again, the tendency of late years has been to reduce the number of sizes jigged, and to abandon the very close sizing which formerly characterised the method.

The arguments for close sizing are drawn from the well-known laws governing the fall of bodies in water, which may be stated as follows:—A body falling in still water moves at first with accelerated velocity, as in a vacuum. The resistance of the water, however, increases with the square of the velocity, and finally equalises and neutralises the accelerating force. Thereafter the grains move with uniform falling velocity.

It is argued that, in order to effect a separation by the water-currents of a jig, the range of size in the grains treated must not exceed the size-ratio of equal-falling grains. But the conditions which obtain in jigging are not the same as in the case of bodies falling freely in water. We have to deal not with single isolated grains, but with numbers of these grains moving together. The

Jigging—continued.
smaller grains move in the interspaces between the large grains, and, consequently, in constricted channels. The large grains, also, so far as their movements are independent of the surrounding grains, as in the separation of gangue from ore, and of one mineral from another, move in the interstitial channels between the other grains. These channels must have great influence on the movement of the grains. Nevertheless many have been content to assume the formula for free-falling grains as of universal application, and have drawn therefrom the arguments and data for the close and accurate sizing characterising the Continental system of ore-dressing. It is, however, possible to effect a very satisfactory separation on jigs, with material sized between wide limits only, and in a very imperfect manner, or even entirely without sizing.

The principal advantage of the English method of jigging is that is dispenses with the operation of sizing by screens. The plant is thus simpler and cheaper, and the expense of treatment less. If the jigging be conducted entirely without size-classification, it has the further advantage that very fine material can be treated successfully on jigs, which would otherwise have to be treated on tables. The bulk of the gangue, both fine and coarse, is thus at once separated by the "roughing-jigs," leaving but a small amount of rich stuff to be treated on the finishing-jigs and tables. As the treatment of the fine stuff by itself is troublesome, and the capacity of slime-jigs and tables is small, the plant and method of treatment are still further simplified and cheapened.

The English method is especially well suited to the concentration of low-grade ores on a large scale.

The principal objection in practice to the English system of jigging is the imperfect concentration of the material passing through the jig-bed. The hutchwork is much richer when the stuff is sized before jigging. This difficulty is overcome by the re-treatment of this hutchwork on finishing-jigs. At Bonne Terre, the hutchwork is classified in pointed boxes, the sands re-treated on jigs, and the slimes concentrated on side-bump table.

Munroe's investigations suggest means whereby the hutchwork can be enriched without the necessity for this second treatment. By treatment of fine and coarse material together on the same jig, interstitial channels will be formed between the coarse grains, in which the fine stuff can be very perfectly concentrated. Again, by decreasing the mesh of the jig-sieve, the size of the interstitial channels may be reduced, and still finer material successfully concentrated. Experiments made to test the possibility of reducing the number of grades of sand, developed the unexpected result that the hutchwork was much improved by jigging coarse and fine stuff together, the reason for which is now clear. So also at Bonne Terre, where, however, the problem is complicated by the necessity of running the roughing-jigs so as to suck as much fine stuff through the sieve as possible.

Jigging—continued.

The problem to be solved in connection with the English method of jigging is to determine the best method of treating the stuff too fine to be concentrated successfully in the interstitial channels of the jig-bed.

The first and most obvious method is to separate the fine stuff by water-classification before jigging the sands. The objections to this course, are, first, the quantity of water required to effect the separation of the slime; and second, the fact that much fine stuff will be sent to the tables that could be treated successfully on the jigs.

A second plan is to separate the fine stuff from the tailings of the jigs by proper classifiers. This is perfectly feasible, and has the advantage that the jigs can be so run as to produce a rich hutchwork. This plan requires large settling-tanks, and a considerable amount of clean water to effect the separation of the slime. It has the advantage over the plan of separating before jigging that the fine mineral is partly concentrated and saved by the jigs.

A third plan, which will effect a partial solution of the problem, is to run the jigs so as to take full advantage of the interstitial action. By reducing the mesh of the jig-sieve, finer material can be concentrated. With a given maximum size for the coarse sand-grains, however, a limit will be found beyond which the mesh of the sieve cannot be reduced. Possibly it may be found practicable to use a three or four-sieved jig, with different mesh on each sieve, and, by varying the stroke of the pistons, to adapt each sieve to the saving of a certain grade of sand. At Lake Superior the tail-sieves have finer mesh than the head-sieves. Or the roughing-jigs may be run with little under-water, so as to suck all, or nearly all, of the fine stuff through, thus ensuring poor tailings, and the hutchwork may then be treated again on jigs of finer mesh. These finer jigs should be run in the same way, and their hutchwork should be treated on tables.

By one or another of the above methods, it may be found practicable to save and treat the slime without using classifiers to separate it from the sands.

A fourth plan is to conduct the crushing so as to produce a minimum amount of slime; for example, by a system of gradual crushing, using two or more sets of rolls; or by coarse-crushing, followed by jigging and fine-crushing of "raggings" only; or, again, by calcining the ore so as to make it more friable. By one or another of these methods it may be possible to limit the production of fine stuff, so that in many cases it may be allowed to escape without serious loss.

The following are the main points developed by Munroe's investigations:—

1. Bodies falling through water in a tube do not attain as high a velocity as in falling through the same medium in large vessels.

Jigging—continued.

2. The falling velocity is but little affected when the diameter of the body is less than $\frac{1}{10}$ that of the tube.

3. The falling velocity is the more retarded as the diameter of the body approximates that of the tube.

4. A sphere $\frac{4}{10}$ the size of the tube will develop the greatest falling velocity, and will require a current of maximum velocity to support or raise it.

5. Grains falling *en masse* are really moving in confined channels, and follow the law of the movement of bodies in tubes. The falling velocity, and the velocity of the current necessary to support or raise the mass of grains, increase and diminish with the distance apart of the grains.

6. The diameter of the channel in which the single grain moves equals the cube root of the volume of the grain with its proportion of the interstitial space, or, in other words, the cube root of the space occupied by the grain.

7. In a mass of grains of different sizes, the large grains move relatively in smaller channels than the small grains. The ratio of the diameters of equal-falling grains of quartz and galena, under such conditions, is 31 to 1, instead of 4 to 1, which latter ratio holds good for free-falling grains only.

8. The formulæ for grains moving in tubes, when applied as above to grains moving *en masse*, enable us to compute the velocity of jig-currents and thus determine the proper length and number of strokes of the jig-piston. The old formulæ gave results many times too large.

9. Close sizing is not necessary for the separation of different minerals by jigging, unless the difference in specific gravity is small.

10. Downward currents are apparently necessary to success in jigging through a bed. This requires confirmation by experiments on a larger scale.

11. Very fine material, less than $\frac{1}{10}$ millimeter diam., can be treated successfully on jigs, if treated with coarse stuff, the concentration taking place in the small interstitial channels between the grains forming the mineral bed. For the treatment of fine stuff on jigs, close sizing is a positive disadvantage. Jigs work well on mixed stuff, and very badly on fine stuff alone. Stuff less than $\frac{4}{10}$ the size of the smallest interstitial channels cannot be treated successfully in this way.

12. The size of the mesh of the jig-sieve has a very important influence, and must be proportioned to the work to be done.

GOLD.

SLUICES.

Sluices must vary in length according to the nature of the dirt being washed, and must be determined in each instance by actual experiment, an increase being necessary if assays of the tailings show a loss of gold. The sluice is generally run on a wide curve, the outside edge being raised $\frac{1}{2}$–1 in. to equalise the wear and tear, because in a straight sluice the velocity of the current would be likely to carry away much of the dirt without disintegrating it. The dimensions of the sluice are determined by the quantity of material to be treated, which is governed by the water supply. One 6 ft. wide by 3 ft. deep, with a 4–5 per cent. grade, will take about 3500 miners' "inches"; one 4 ft. wide by $2\frac{1}{2}$ ft. deep, with $2\frac{1}{2}$ per cent. grade, 1200–1500; or with 4 per cent. grade, 2000 miners' "inches." The water must be in sufficient depth to cover the largest boulder likely to be encountered, so that the body required will vary with the coarseness or fineness of the dirt. With too much water, the riffles are likely to pack, and the yield of gold will be less, increasing with low grade and small body of water. If water is plentiful and cheap, it will to a certain extent atone for low grade; but with water scarce and dear, a high grade is essential.

GOLD SLUICING: *Water consumed.*

Generally speaking, ordinary gravel needs 4 per cent., and coarse gravel 6–7 per cent.: the heavier the gravel the steeper the grade, and the more water necessary; 4 per cent. is very commonly used, increased to 6 and even 8 for clay, and reduced sometimes to $1\frac{1}{2}$ per cent. for very light dirt. The "No. 8" mine of the North Bloomfield Gravel-Mining Co. required an average of 534 cub. ft. of water to wash 1 cub. yd. of gravel; or, in other words, the gravel at this locality required for moving it an expenditure of water nearly equal to 20 times its bulk. At the Blue Tent Co.'s mine, where careful record has been kept of the amount of gravel washed, water used, &c., for the past few years, the various kinds of gravel met with were moved at the rate of from 2·38 to 10·12 cub. yd. per miners' "24-hour inch" (which is considered on the San Juan divide equal to 2230 cub. ft. of water; in the Bear River mines, about 2200),

Gold Sluicing—continued.
or, in other words, the gravel required, according to its condition, from 8 to 34 times its volume of water to disintegrate it and carry it into the sluices. Hague adopted 7 cub. yd. as the amount of gravel which, on the average, in the divide between the South and the Middle Yuba, could be moved by a "24-hour inch" of water, and this is said by Prof. Pettee to be corroborated by the results obtained at Smartsville; 7 cub. yd. to the "24-hour inch" gives an amount of gravel not quite $\frac{1}{12}$ of the volume of the water used. Ashburner considered that a "24-hour inch" of water would move only about $3\frac{1}{2}$ cub. yd. of the lower portion of the gravel deposit in Bear River and its tributaries. This gravel may be considered as representing the hardest kind ordinarily worked by the hydraulic method. It appears, therefore, that a "24-hour inch" of water will disintegrate and carry into the sluices 2–10 cub. yd. of gravel, according to the character of the material.

GOLD SLUICING: *Utilising current of large rivers.* (Thomson).

A screw 8 ft. diameter will give 8 H.P., and can be immersed and attached to any fixture. It will raise one Otago sluice head of water (equal to 95 cub. ft. of water delivered per minute) to an elevation of 70 ft., or 7 heads 10 ft., without intermission. The screw may be made of timber, and can be put together by any blacksmith or carpenter. Minor scientific faults in its form are compensated by an excess of current-power. The accessories requiring skill in their construction are a brass force-pump and some rubber tubing. With a screw or fan 15 in. diameter, with blades set at an angle of 20° to the disc, in a 2-mile current, the revolutions are nearly 1 per second; the pistons of the pump are worked by a crank, propelling the contents once per second; the diameter of the cylinder is $\frac{3}{4}$ in.; stroke of piston, 2·7 in.; quantity of water per stroke, 1·1925 cub. in., or 71·55 cub. in. per minute, or 59·5 cub. ft. or 368·9 gal. per 24 hours; cost 4*l.* or 5*l.* The capacity and cost increase, of course, with the size. The whole apparatus is easily repaired, and can be removed at will.

GOLD SLUICING: *Cost.*

Under favourable conditions for hydraulic washing two men can do all the work in a washing that uses 300 miners' "inches" of water. Under such circumstances, 1 pipe will break down as much as 3 can wash away; on the other hand, 3 pipes are sometimes required to break down what 1 can wash away. The water is generally considered capable of carrying away $\frac{1}{5}$ of its own weight of gravel.

Table 96.—Average cost for the La Grange Company. (*Bowie*).

Per oz. of Metal produced.	s.	d.	Per cub. yd. treated.	d.
Water	5	10	Water	0·4
Labour	28	4	Labour	1·8
Material	7	6	Material	0·5
Officers	3	11	Officers and contingent expenses ..	0·3
Contingent expenses	1	1		
Taxes	0	4		
	47	0		

With light pressure and low grade.

Table 97.—With heavy pressure and low grade.

For heavy pressure and 4 per cent. grade, an example may be found in the North Bloomfield Company's figures, per oz. of metal produced:—

	s.	d.
Labour	16	0
Blocks and lumber	2	0
Explosives	4	0
Materials	3	8
General expenses	2	11
Water	8	0

The following promiscuous costs per yd. may also be quoted:—
3*d.*; 1½*d.*; 1¼*d.*; 1*d.*; 1*d.*; averaging from 1*d.* to 2¾*d.* per cub. yd.

GOLD SLUICING: *Yields and Cost.*

Of the yield from hydraulic workings, those lying between the Middle and South Yuba have averaged, according to Laur, 8*d.* per cub. yd. and according to Prof. Silliman, 15*d.* per cub. yd. Various yields have been:—2*s.* 11½*d.*; 2*s.* 6*d.*; 12½*d.*; 7½*d.*; 6¼*d.*; 5*d.*; 2⅜*d.* The last mentioned figure refers to the Gold Run district, where all the conditions were extraordinarily unfavourable. The average yield of the Smartsville gravel is stated by Whitney at about 23c. (11½*d.*) per cub. yd.

Gold Sluicing—continued.

In the Sierra Nevada, when the top gravel only is washed, it is thought to do very well if it yields 10c. to 15c. (5*d.* to 7½*d.*) per "inch" of water for 10 hours. On the North Bloomfield Co.'s mine in 1870–71, the yield of surface gravel was 16c. (8*d.*) per "24-hour inch," or 6$\frac{6}{10}$c. per "10-hour inch." From 1870 to 1874, the yield was only 13$\frac{6}{10}$c. per "24-hour inch," equal to 5$\frac{66}{100}$c. per "10-hour inch." In 1875, the top gravel, including a little blue gravel, but nothing within 40 ft. of the bed-rock, yielded 19$\frac{2}{10}$c. per "24-hour inch," or 8c. per "10-hour inch." It is quite probable, however, that the water in this mine, furnished as it is from the company's own ditch, is much more lavishly used than in mines where it is purchased, and the relation of water to product would, on that account, be an unfair criterion for other mines. At Columbia Hill, where only top gravel has been washed, its yield in several instances has varied from about 20c. (10*d.*) to 58c. (29*d.*) per "24-hour inch," affording in the instance last referred to exceptionally good profits.

Four companies at Howland Flat and Potosi—the Down East, Union, Hawkeye, and Pittsburg—took from about 2,365,000 sq. ft. of surface, 2,251,653 dols. 95c. (470,094*l.* 6*s.* 5*d.*), the pay-gravel being estimated at 4½ ft. in thickness. This would give an average of 95c. (3*s.* 11½*d.*) per sq. ft. of surface, or 5 dols. 70c. (23*s.* 9*d.*) per cub. yd. of gravel washed. This material was mined, it is stated, at a cost of 47c. (23½*d.*), leaving a profit of 48c. (2*s.*) per sq. ft. At Grass Flat, in the Pioneer Company's ground, the yield per cub. yd of gravel is said to have been 1 dol. 59c. (6*s.* 7½*d.*)

At Allan's Flat, Yackandandah, Victoria, the ground washed off was about 30 ft. deep, the water used was 500 gal. a minute, and the inclination of the sluice was 1 in 25; 3 men worked 150 cub. yd. per diem. The daily expenses of a claim were:—

	£	*s.*	*d.*
3 men at 8*s.*	1	4	0
360,000 gal. of water at 0·33*d.*	0	10	0
Wear and tear	0	6	0
	2	0	0

Consequently a yield of $\frac{4}{5}$ gr. of gold per cub. yd. covered all expenses.

A hydraulicing claim on Dunedin Flat, Kumara, New Zealand, yielded 1735 oz. of gold from a block of 22,403 cub. yd., or an average of 31 gr. per cub. yd., working a face 35 ft. deep. Shares in this claim sold readily at 400*l.* each.

Table 98.—*Cost of Producing* 1 *oz. Troy of Gold in Californian Hydraulic Claims.* (Egleston.)

	La Grange Co.		North Bloomfield Co.	
	$	£ s. d.	$	£ s. d.
Water	1·43	0 5 11½	2·09	0 8 8½
Labour	6·85	1 8 6½	3·93	0 16 4½
Materials	1·81	0 7 6½	0·88	0 3 8
Explosives	..	..	0·98	0 4 1
Blocks and lumber	..	..	0·50	0 2 1
General expenses	0·94	0 3 11	0·70	0 2 11
Contingent expenses	0·26	0 1 1	..	..
Taxes	0·09	0 0 4½	..	..
	11·38	£2 7 5	9·08	£1 17 10

Value of gold = 3*l.* 17*s.* 2½*d.* per oz.

Table 99.—*Yield of Californian Mines.*

	Height of Bank.	Yield per cub. yd.	
	ft.	cents.	*d.*
Smartsville Claims, Yuba Co. ..	112	19·5	9¾
Blue Tent, Nevada Co.	180	15	7½
North Bloomfield, Nevada Co ..	180 to 260	4 to 6·5	2 to 3¼
Gold Run, Placer Co.	200	4·8	2¾
Columbia Hill, Milton Co. ..	100	4·33	2¼
La Grange, Stanislaus Co. ..	18 to 100	2·5 to 15·5	1¼ to 7¾
Patricksville, Stanislaus Co.	40 to 60	4·33 to 18·5	2¼ to 9¼
Dardanelles, Placer Co...	150	13	6½

Table 100.—*Cost and Yield per cub. yd.*

	Cost.		Yield.	
	cents.	*d.*	cents.	*s.* *d.*
Roach Hill	6	3	60	2 6
Richardson	3	1½	15	0 7½
Iowa Hill..	2·5	1¼	71	2 11½
Independence	2	1	25	1 0½
Wisconsin	2	1	12·5	0 6¼

Table 101.—GOLD: *Sluicing Tunnels.*

Name.	Length of Tunnel.	Average Grade of Tunnel.		Cost (reported).
		In. per Sluice Box.	Ft. per 100.	
	ft.			£
North Bloomfield ..	8000	6¼ in. per 12 ft.	4¼	100,000
American	3900	10¼ ,, 14 ,,	6¼	28,040
French Corral	3500	8 ,, 14 ,,	4⅔	33,000
Bedrock	2600	9 ,, 14 ,,	5¼	..
Farrell	2200	6 ,, 14 ,,	3½	..
Sweetland Creek.. ..	2200	8 ,, 14 ,,	4⅔	18,000
Manzanita	1740	7 ,, 14 ,,	4⅙	12,000
Boston	1600	10½ ,, 12 ,,	7¼	8,000
English Mine	1400	12 ,, 14 ,,	7	..

The tunnel forms the outlet of the workings, and in it (as well as beyond it) are placed the sluice-boxes for catching the gold. The dimensions of the tunnel will therefore depend on those of the sluices, allowing about 2 to 2½ ft. of extra room; and the size of the sluices will vary in proportion to the quantity of material and water to be passed through them, and the duration of the mining season. For single sluices about 6 ft. square, running 8 or 9 months in the year, a tunnel 8 ft. high and 7 ft. wide is commonly made, which at 4 per cent. grade will consume 2000 to 2500 miners' "inches" of water. For a consumption of 3000 to 3500 miners' "inches" of water, larger tunnels and double sets of sluices are preferable. The grade should be as high as can safely be used, both for the purpose of breaking up the material thoroughly, and to ensure against choking, at the same time that it must not be so steep as to create undue wear and tear of the sluices; it will vary, in inverse proportion to the size of the sluice, from 4 to 7 per cent., commonly the former, and with very light and friable dirt even 3½ per cent. may suffice. In length, tunnels vary according to circumstances from hundreds to thousands of feet; and the depth between their outlet and where they abut on the shaft bottom should be 50 to 70 ft., it being seldom easy to get more.

GOLD: *Sluicing Yields.*

The method of stating the yield of deep gravels varies. In some places, the standard is the car-load, calculated at 16–20 cub. ft. = 1 ton; but as the size of the car depends upon the size of the tunnel, the car-load, without giving dimensions, cannot be a standard of value. About 9 cub. ft. of ground in place, when broken, will fill a box of 12 cub. ft. capacity. An estimate, based upon cubing the feet, without explanation, would be erroneous. Another way of estimating the yield is per ft. of channel. In some places the value is expressed at per acre or at per superficial yard of channel-ground, but the height of the ground is not uniform. In some places it is 3, and in others 4 or 5 ft. The only way to definitely express the

Sluicing—continued.
value is by the cub. yd., but this method is not in general use, so that it is not easy to get a standard of the value for comparison.

To pay, gravel should contain, under ordinary circumstances, 2*s.* to 4*s.* worth of gold per car-load of 16 cub. ft. The minimum value of ground to be worked should thus be 2*s.* to 4*s.* per cub. yd. of gravel extracted.

Yields of Gold from various deep leads.—One field of 20 acres produced 16,440 oz. of gold; the average at another diggings was 2 dwt. 22 gr. per ton; at a third, 1 to 1½ dwt. per load; at a fourth, 5 dwt. per ton; at a fifth, 6 dwt. per ton; at a sixth, 15 dwt. per load. In a seventh instance, one mile of lead yielded 170,000 oz. equal to 32 oz. per lineal ft. These figures all refer to Victoria, and are on the authority of Brough Smyth. In California, 50c. (say 2*s.*) per cub. yd. seems to be the average value of the wash-dirt in the deep leads; but Raymond mentions four companies which made respectively 10·80 dols., 8·10 dols., 9·45 dols. and 7·38 dols. per sq. yd., which gives an average of 95c. (3*s.* 11½*d.*) per sq. ft. of ground 4½ ft. high, or 5·70 dols. (23*s.* 9*d.*) per cub. yd. of gravel.

Table 102.—GOLD: *Sluicing Ditches.*

Name.	Length of Ditch.	Width of Top of Ditch.	Width of Bottom of Ditch.	Depth of Ditch.	Cost of Ditch.	Average Grade per Mile.	Discharge in Miners' Inches.
	miles	ft.	ft.	ft.	£		
Milton	100	6	4	3·5	52,000	14·5	3000
North Bloomfield.. ..	55	8·65	5	3·5	84,000	14	3200
.. .. .. (1.)	60	8	6	4	..	..	2200
Spring Valley .. (2.)	52	6	4	3·5	..	..	2000
Hendrick's	46·5	6	4	2	27,000	9·6	..
San Juan	45	..	..	..	59,000	..	1300
South Yuba .. .. (3.)	35	8	4	4	..	..	..
Excelsior	33	8	5	4	..	9	1700
La Grange .. .. (4.)	20	9	6	4	90,000	7·5	3000
Eureka Lake..	18	..	..	..	86,000	..	2800
Union	15	8	4	3·5	..	13	1200
Boyer	15	8	4	3·5	..	13	1200
.. .. .. (5.)	..	6·5	4	3	..	11·2	3000
.. .. .. (6.)	..	..	3	3	..	..	2000

1. On the line of the ditch are 4 miles of iron pipe, 30 in. diameter, one section of which conducts the water across a branch of a river. It is laid as an inverted siphon, and has a vertical depression of 856 ft. The receiving arm has a head of 180 ft. vertical pressure; length of siphon, 2¼ miles.

2. This has 3¼ miles of 30-in. iron pipe.

3. With a subsidiary ditch, grade 10 ft. per mile, current 2¼ ft. deep. It is carried across a narrow cañon by a wire suspension flume, and across another by a truss flume with a span of 60 ft.

4. Most of this ditch is hewn in granite.

5. The line is graded 7¼ ft. wide, and excavation made close into the bank, leaving not less than 1 ft. of solid earth on the outside.

6. To cross a creek the water is led into a 27-in. pipe, 420 ft. long, and with a depression and elevation of 75 ft.

Table 103.—GOLD: *Sluicing; Working Details of Tunnel Claims near Dogtown, Calaveras County, California.* (Min. Comr. Rep.)

	Hammerschmidt, Hensel & Co.	Barney, Hurle & Co.	Bully Company.	Buckeye Company.	Deitrich & Co.
Inches of water used in sluice washing	25 to 30	30	30	30	30.
Inches of water used in hydraulic washing	20.				
Height of fall	100 ft.				
Supply of water lasting in the year	6 to 7 months	6 to 8 months	6 to 8 months	6 to 8 months	6 to 8 months.
Cost of water (sluicing) per day	$4	$4	$4	$4	$4.
Cost of water (hydraulic) per week	$20.				
Air-shafts	One of 70 ft., one of 148 ft.	One of 105 ft.	4	4	10.
Length of tunnel at present	1500 ft.	One of 200, one of 400, and one of 300 ft.	700 ft.	1000 ft.	1200 ft.
Height of drift (all pay-dirt)	6 ft.	$4\frac{1}{2}$ to $5\frac{1}{2}$ ft.	4 ft.		
When this claim commenced	In 1865	In 1862	1870	1870	1870.
Area of ground drifted out and worked	9166 superficial sq. yd.	5600 superficial sq. yd.			
Number of cubic yards drifted out	18,332	7500 sq. yd.	3000.		
Length of ground unworked	400 ft.	600 ft.	1000 ft.		
Average of cement-gravel extracted per day	20 to 25 car loads; about 25 sq. yd.	15 to 20 sq. yd.	Over one-half.		
Quantity of refuse left in the stope	Over one-half	Over one-half	2000 sq. yd.		
Quantity of gravel-cement washed during last year and extracted	2200 sq. yd.	Not washed	$700.		
Yield of cement-gravel washed	$4 to $5 per sq. yd.	$4	$700.		
Total yield last year	Over $8000	Not washed out			
Total yield since commencement of this claim	$70,000	$30,000.			
Gold, description	Small flat particles	Both coarse and fine.			
Wages paid to underground-drifters	$2·50	$2·50	$2·50.		
Number of men hired	4.				
Number of men working	8	4	4	4	4.
Composition of deposit	Red soil, small and large white and blue quartz boulders, pieces of dark blue slate, quartz, and mica slate, cemented granite gravel.	Red soil, quartz, gravel, slate, granite, sand—all cemented.	Gravel, cemented.	Gravel, cemented.	Gravel, cemented.
Bed-rock	Dark blue slate, full of cubical pyrites.	Dark blue slate, veins of quartz.	Blue slate	Blue slate	Blue slate.
Direction of tunnel and course of deposit-channel	E.N.E.	E.	S.E.	S.E.	S.E.

GOLD: *Sluicing; Cost of Tunnelling at Red Point, Placer Co., Calif.*

It is the intention to tap and work an ancient gravel channel which is known to exist under the ridge forming the upper portion of the Forest Hill divide. For this purpose a tunnel was located in Red Point Cañon, about 1½ mile above the town of Damascus. An air compressor is located 200 ft. vertical above, and about 300 ft. distant from, the mouth of the tunnel, the air being conveyed through a 3-in. pipe, which in the tunnel has valves and blow-outs every 500 ft. for the purpose of ventilation. There are no other pipes in the tunnel, except a 1-in. water-pipe for drilling use. The tunnel runs diagonally across the strike of the rocks, which consist of alternate strata of slate, impregnated with iron pyrites, diorite, and masses of white barren quartz.

Table 104.—Actual Cost of 1552 ft. of Tunnel 7 × 8, exclusive of Management, up to Februrary 1, 1887.

	Total.			Cost per running foot.			
	$	£	s.	$	£	s.	d.
Total labour (pay roll), including 100 ft of timbering	11,418·87	2283	15	7·36	1	10	8
Powder. 10,567 lb. Giant No. 2, and 325 lb. No. 1, at 26½ c., 41½ c., 10 per cent. off	2,641·64	528	5	1·70	0	7	1
Fuse. 39,650 ft. at $5·50 per mille, and caps $45, delivered..	263·07	52	16	0·17	0	0	8½
Wood. 402 cords, at $2·75	1,105·50	221	0	0·71	0	2	11½
Charcoal. 1604 bushels, at 20 c. ..	320·80	64	0	0·21	0	0	10½
Candles. 1760 lb., at 16½ c.	290·40	58	0	0·19	0	0	9½
Foot planks and ties. 7355 ft. of lumber, at $20 per mille	147·10	29	10	0·09	0	0	4½
Timbers. 43 sets, at 60 c. per running foot	46·76	9	6	0·03	0	0	1½
Steel rails. 16,640 lb., at $60 per ton	510·00	102	0	0·33	0	1	4½
Air and water pipes, 3 and 1 in., at 18 c. and 5¾ c. per ft.	521·86	104	4	0·35	0	1	5½
Horse feed	281·25	56	0	0·18	0	0	9
Materials, steel, oil, tools, &c... ..	693·00	138	0	0·45	0	1	10½
Freights, at 1·25 per 100 lb.	1,000·00	201	0	0·64	0	2	8
Totals	$19,239·85	£3847	16	$12·40	£2	11	8

Table 105.—Cost of Surface Improvements, Plant, and Tunnel.

	Total Cost. $	£	s.
Road, 6500 ft. long; average grade, 1 ft. in 10. Average force of men per day, 9·2. Including surveys and powder..	963·00	192	12
Yards, dump and trails. Average force of men, 5·6. Total cost, including crib-work, timber, and powder .	508·05	101	11
Boarding-house, office, blacksmith shop, stable, powder-house, wood-shed, framing sheds, snow-sheds, &c. ..	2,310·10	462	0
Water-works. Long dam, 2-in. pipe line 2800 ft. long, in ditch and covered. Average force of men per day, 2·74. Total cost, including surveys, powder and pipe	604·94	120	16
Air-compressor erection. Average force of men per day, 5. Total cost of labour ..	970·00	194	0
One straight-line compressor, 16 × 16 × 24; one 34 × 16 steel boiler, complete; air-tank; pump, 3 × 3¼; eclipse drills and columns; pipe connections, extras, freight, and building 30 × 40..	7,819·86	1564	5
8 iron cars ..	1,200 00	240	0
2 tunnel horses, 2 team horses, and buckboard ..	705·00	141	0
Total cost of plant, &c., &c... ..	$15,080·95	£3016	4

GOLD: *Cost of Alluvial Mining in Victoria* (Smyth).

At Ballarat the average cost of raising and puddling wash-dirt and getting out the gold in several mining properties is 7*s.* 3*d.* per ton, and the cost of puddling and sluicing in two instances is 1*s.* 7¼*d.* per ton.

At Clunes, the average cost in one alluvial mine is 10¾*d.* per ton for puddling, and the average cost of sluicing is 3½*d.* per ton.

At Sandhurst, the average cost of raising "cement" is 3*s.* 6*d.* per ton; the average cost of carting, crushing, and extracting the gold is 8*s.* per ton; and the average cost of puddling or sluicing is 3*s.* per ton, including cartage.

At Maryborough, the average cost in three instances of raising cement is 21*s.* 8*d.* per ton; puddling, 2*s.* 6*d.* per ton.

At Castlemaine, the average cost in one claim of breaking cement is 21*s.* per ton; raising it to the surface and delivering it at the machine, 4*s.* 9*d.* per ton; crushing the cement and extracting the gold, 3*s.* 9*d.* per ton. The average cost of puddling by one party of miners is 1*s.* 2*d.* per ton.

At Maldon, the average cost in one mine of raising cement and delivering it at the machine is 1*s.* 6½*d.* per ton; and the cost of crushing and extracting the gold is 2*s.* per ton At the Forty-foot lead, the average cost of raising, carting, and puddling is 6*s.* 6*d.* per ton.

At Hurdle Flat, Ovens district, ground 16 ft. 6 in. deep, sluice in rock, 4 gr. of gold (6*d.* per load) pays well; four men get down and wash 1 ton of dirt every 5 minutes.

GOLD SLUICING : *Nozzles* (Van Wagenen).

To estimate quantity of water discharged from nozzle of pipe, extract the square root of the head, and multiply this root by 8·03; the product will be the velocity in ft. per second with which the water escapes from the mouth-piece. Multiply the area of the mouth-piece by this velocity, and the result will be the discharge in cub. ft. per second. *Ex.*—What quantity of water will be discharged from a pipe, under a head of 100 ft., through a 3-in. nozzle? *Ans.*—The square root of the head (100) is 10, which, multiplied by 8·03, gives 80·3 ft. as the velocity per second. The diameter of nozzle being 3 in. (·25 ft.), its area would be ·25 multiplied by 3·14, multiplied by ·0625 = ·04906 sq. ft., which, multiplied by the velocity 80·3, equals 3·93 cub. ft. discharge per second. The actual discharge is probably about 80 per cent. of the theoretical one in well-made nozzles provided with inside flanges to prevent revolution of the stream, and in this case would be 3·14 cub. ft. per second. This would represent about 115 miners' inches. The power of the stream depends very largely upon its smooth and cylindrical form. The mouth-piece, therefore, should be very smooth, and the arrangements of the pressure or water box so perfect as to exclude all sand, air, and other foreign matters.

GOLD SLUICES : *Dimensions* (Van Wagenen).

The maximum quantity of water which may be advantageously used in a single sluice of correct dimensions when the ground is ordinarily full of boulders, is set down by good practical authorities at 1000 miners' inches. This corresponds to a discharge of 95,000 cub. ft. per hour, which, with gravel and boulders, would represent about double that amount of moving substance in the sluice. When more than this is used the current will be so strong that men cannot work to any advantage in the head-box. Sluices intended to clear off top dirt must be short and large. In this case the top dirt is presumed to be nearly free of gold and of boulders. First decide upon the largest sized boulder which shall be allowed to go through the flume. If it be 2 ft. diameter, the flume must carry at least 2 ft. deep of water. The bottom should be 1¾–2¼ times the height of the side, or, taking the side at 30 in., the bottom should be 52½–67½ in. wide. If, however, the ground is free from large boulders, it is merely necessary to ascertain the dimensions best adapted to carry the greatest economical quantity of water (1000 in.) or 27·1 cub. ft. per second. Double this discharge to make room for the gravel. The flume must then discharge 54·2 cub. ft. of material per second. Having ascertained the area of section in sq. ft., resolve it into correct dimensions by the following rules:—

Rule 1. The width to be 2¼ times the sides.

Sluices—continued.

Multiply the area in sq. in. by 4, and divide the product by 9. Extract the square root of the quotient. The result will be the height of side in inches.

Rule 2. The width to be $1\frac{3}{4}$ times the sides.

Multiply the area in sq. in. by 4, and divide the product by 7. Extract the square root of the quotient. The result will be the height of side in inches.

GOLD SLUICES: *Grade* (Van Wagenen).

The moving power of water in sluices may be approximately judged by—

Table 106.

16 ft. per minute	begins to wear away fine clay.
30 „ „	just lifts fine sand.
39	lifts sand as coarse as linseed.
45	moves fine gravel.
120	„ inch pebbles.
200	„ pebbles as large as eggs.
320	„ boulders 3–4 in. thick.
400	„ „ 6–8 „
600	„ „ 12–18 „

Hence following rule for establishment of grades in sluices when the velocity needed is decided upon:—Multiply the velocity expressed in ft. per second by itself, and the product by the wet perimeter in ft. Divide this result by twice the area in sq. ft. The result is the total fall in ft. per mile. *Ex.*—What grade must be given to a sluice 12 in. broad and 6 in. deep, that it may carry a velocity of 320 ft. per minute, or 5·3 per second? *Ans.*—Multiply the velocity (5·3) by itself, and the product by the wet perimeter (24 in. = 2 ft.), we have 56·18. This, divided by the area (72 sq. in. = ·5 ft.), and doubled = 56·18, which is the fall in ft. per mile. To reduce grades expressed in ft. per mile to in. per box of 12 ft. multiply by ·027. Thus, a grade of 56·18 ft. per mile equals a grade of 1·5 ($1\frac{1}{2}$) in. per box. To reduce to in. per rod (16 ft.), multiply by ·036.

GOLD SLUICING: *Specification of Stores Required for Opening Hydraulic Mine.* (Kirkpatrick.)

10 cwt. $\frac{7}{8}$-in. borer steel.
1 doz. steel mallets for boring, 7 lb.
12 hand-saw files.
3 tenon-saw files.
15 6-in. pit-saw files.
15 8-in. cross-cut saw files.
3 smiths' sledge hammers, 9 lb.
1 cwt. cast steel for steeling picks.

Specification—continued.

1 doz. riveting hammers.
1 doz. set tools for ¼-in. rivets.
1 doz. snap tools.
6 hand hammers, Nos. 10 and 12 tester heads.
10 doz. miners' steel shovels, diamond points.
5 doz. Cornish picks.
10 doz. handles for ditto.
1 doz. long Colonial pattern felling axes.
2 small portable forges.
1 best black staple smiths' vice.
2 anvils (farriers' pattern), 150 lb. each.
2 grindstones 27 in. diam. (1 coarse, 1 fine).
2 sets screw stocks, dies, taps, and wrenches complete, from $\frac{7}{16}$ in. to ¾ in. and ⅞ in. to 1¼ in. engineers'.
3 expanding spanners.
20 cwt. best cut nails 2½ in.
10 cwt. ,, ,, ,, 3½ ,,
16 cwt. ,, ,, ,, 4 ,,
4 cwt. ,, ,, ,, 4½ ,,
4 cwt. ,, ,, ,, 5 ,,
4 cwt. spikes, 7-in.
4 cwt. ,, 9 ,,
1 doz. riveting blocks.
2 doz. pairs of tools for riveting pipes.
500 lugs for ditto.
4 sets carpenters' bench planes (jack, trying, and smoothing).
4 3-in. bench screws and nuts.
6 4-lb. carpenters' axes, with handles.
2 sets socket mortice chisels, with handles.
3 pair 12-in. wing compasses.
6 2-ft. rules to fold 12 in.
2 ,, ,, ,, ,, 6 ,,
4 carpenters' set stones.
2 pair pincers.
2 2-ft. iron squares, graduated inches.
4 14-in. carpenters' plated squares.
4 6-in. ,, ,,
4 doz. carpenters' pencils.
3 spirit levels, set in straight edge 30 in. long, with handle on top to protect level.
6 hand-saws (7 teeth to inch).
4 fine ditto, for cross cutting.
4 carpenters' table saws.
3 12-in. tenon saws.

$$\left.\begin{array}{l}\text{4 7-ft. pit saws (for pine)}\\ \text{6 5-ft. cross-cut saws (for oak)}\end{array}\right\}\text{complete with bow and gear.}$$

2 iron braces, 24 bits to each.
4 carpenters' marking mortices.

Specification—continued.

4 hand-saw sets.
6 pit-saw sets.
6 14-in. drawing knives.
3 plated spokeshaves.
6 12-in. turnscrews.
2 ploughs and irons.
6 adzes (12-in. handles).
6 ½-in. screw augers.
6 ¾-in. augers.
6 ⅞-in.
6 1⅛-in.
3 1¼-in.
3 1½-in.
3 2-in.
3 doz. caulking irons, single crease.
4 plated angle bevels.
2 joiners' cramps, 6 ft. long.
60 ft. 1¼-in. bar iron.
130 lb. soft iron wire, No. 12 B.W.G.
1 cwt. white lead.
16 door locks (different).
2 doz. padlocks.
5 doz. 4-in. butt hinges.
2 gross 1½-in. screws.
1 gross 1-in. screws.
7 gross smaller (for locks).
10 pieces of unbleached calico (for making tight joints in pipe).
2 doz. ordinary iron buckets.
2 doz. black iron scoops.
1 doz. hard brushes.
20 bottles mercury.
2 No. 5 "monitors," with deflectors and nozzles.
2 18-in. vacuum valves.
2500 ft. 18-in. diameter pipe, No. 14 B.W.G., ¼-in. rivets.
500 ft. 15-in. diameter pipe, No. 14 B.W.G., ¼-in. rivets.
100 ft. 30-in. diameter, tapering to 18-in., No. 14 B.W.G., and ¼-in. rivets.
2400 ft. run of 11-in. by 3-in. timber, cut into 11-in. by 1½-in., in 20–22 ft. lengths, second St. Petersburg deals.
4000 ft. run 6-in. by 4-in., in 12–22 ft. lengths, third St. Petersburg deals.
1 small distributor.
Melting pots, ingot moulds.
Chemicals—borax, carbonate of potash and soda, &c.
Tongs, cobbing hammers, and iron plates.
Blankets, cold chisels, scales and weights.
Red lead, litharge.

The cost of the above will be under 2,000*l*.

GOLD: *Cost and Profit of Quartz Mines.*

Circumstances vary so widely at different mines that no general estimate of cost or profit could possibly be deduced in a form that would have any practical value; but it may be useful to quote the prices paid for crushing quartz in Victoria. These range from a minimum of 4*s*. to a maximum of 15*s*. a ton, the majority being about 5*s*. a ton where water power is available, to 8*s*. and upwards where the motor is steam. The success of a quartz mine depends quite as much on favourable working conditions as on richness in gold. Hence it may happen that a mine carrying 5 oz. of gold to the ton, but badly situated, may be inferior as an investment to another showing only 5 dwt., but favourably circumstanced. There are a great many mines where 3 to 4 dwt. of gold cover every item of expenditure, the excess being clear profit. In fact, one Victorian mine, in the Blackwood Division, satisfied its owners with a yield of $1\frac{1}{2}$-2 dwt. a ton, crushing with water power. On the other hand, mines which have been credited with giving extraordinary assay values have not paid for working. So much depends on local conditions and proper management.

GOLD AMALGAMATING: *Copper Plates.*

From inquiries made of a number of Australian managers, the following inclines per ft. are recommended for copper plates, viz., $\frac{1}{2}$ in., $\frac{3}{4}$ in., $\frac{7}{8}$ in., 1 in., $1\frac{1}{8}$ in., $1\frac{3}{16}$ in., $1\frac{1}{4}$ in., $1\frac{3}{8}$ in., $1\frac{7}{16}$ in., or an average of exactly 1 in. per ft. Bland finds amalgamated plates less efficient than mercury drops and blanket tables, and mentions that the incline depends greatly upon the supply of water—the smaller the supply the greater must be the incline. Clark states that copper plates are generally laid on the ripple tables between the wells of mercury, the object being to bring every particle of the crushed sand, as it escapes from the battery, in contact, as far as possible, with the surface of the mercury, or with the silvered surface of the copper plates. The incline of $1\frac{7}{16}$ in. has been found to work very well for all kinds of stone operated upon, just enough water being used to clear the table. Too much water is objectionable, as it is likely to carry away fine gold. Parker remarks that a great deal depends upon the width of the tables; if they are made the full width of the boxes, more water must be used, or the incline must be greater. Where tables are narrowed to suit the discharge of the gratings, the plate laid immediately under the lip of the box should not have a greater incline than $\frac{3}{4}$ in. per ft. The second plate leading to the blanket strakes should have an incline of 1 in. per ft., and the blanket table $1\frac{1}{2}$ in. per ft. If the tables are the full width of the boxes, the top plate should have $\frac{7}{8}$ in. incline, and the second plate $1\frac{1}{8}$ in. per ft. It must be understood

Amalgamating—continued.
that this last paragraph refers only to plates laid outside the mortar or coffer, as few, if any, Australian mills have plates inside the mortar.

GOLD AMALGAMATING: *Arrastra.*

The working capacity of the simplest arrastra varies from 1 to 2 tons a day. A 12-ft. arrastra driven by power, with heavy drags, making 15 revolutions per minute, may treat two charges of 2 tons of ordinary ore in 24 hours, if very close work is not necessary; but this is the extreme limit of its capacity. The labour required is extremely small. One man per shift can easily take care of two arrastras. Sometimes, when working on tailings, and running by water power, the disposition of the mill is such that the only labour required is for feeding and discharging, being much less than the work of one man. The owner of the mill may do all the work himself. With continuous action, the labour is still smaller, being simply that needed for repairs. Where water power is available, small overshot wheels, or turbine "hurdygurdies," are used. A simple arrastra for mule power can be built for 20*l.* to 30*l.* The cost of 26 complete mills, having 92 arrastras, in 1880, was 137,590 dols., or an average of 5292 dols. for each works, or 1495 dols. (say 75*l.*) per arrastra, including all the rest of the plant. This is considerably above the cost of ordinary arrastra mills. The arrastra at Scales and Wagner's works, Owyhee Co., Idaho (one of the best), produced in 1880 about 10,000*l.* The charge for treating custom ore in lots of 100 tons and over, is 15 dols.; for lots of 50-100 tons, 16 dols.; and a corresponding increase for smaller lots. The plant consists of a battery of 10 light stamps, 2 arrastras, 3 half-ton Wheeler pans, 2 settlers, and a retort.

Table 107.—*Arrastra*: Working figures in summer, on a 12 hours' shift:—

	$	£ s. d.
4 men inside the mill at $4 per 12 hours' shift	16·00	3 4 0
2 labourers in the summer, on 10 hours' shift outwork, at $3·50	7·00	1 8 0
2 engineers in winter, on 12 hours' shift, at $5	10·00	2 0 0
Number of days' work, 330	..	..
Hours of labour to treat 1 ton of ore, 12·7	..	..
Cost of supplies per ton of ore treated	3·95	0 16 0 *
Tons of ore treated in 1880 (tails about 300 tons), 1772·25	..	..
Lowest yield of ore	38·00	7 12 0
Highest yield of ore	600·00	120 0 0
Average	115·85	23 3 6
Yield of the tails	9·50	1 18 0

Table 108.—*Arrastra*: Amount of supplies consumed, and amount per ton of ore treated:—

Items.		Total Consumption.		Consumption per ton of Ore treated.		
		Amount.	Cost.	Amount.	Cost.	
			\$ c.		\$ c.	s. d.
Red fir	cords	575	4,168 75	0·32	2 35	9 5
Quicksilver	lb.	3,000	1,440 0	1·69	0 81	3 4
Salt	"	14,000	420 0	7·89	0 24	1 0
Bluestone..	"	3,000	750 0	1·69	0 42	1 9
Lard oil	gal.	20	40 0	0·01	0 2	0 1
Chemicals and sundries	..	..	200 0	..	0 11	0 5
Total		..	7,018 75	..	3 95	16 0

GOLD AMALGAMATION: *Mercury, purifying* (Kirkpatrick).

The pellicle formed on mercury by absorption of oxygen from the air, can be removed by passing a large and *quite dry* glass tube over the surface, rolling it gently. Or, add a little concentrated sulphuric acid to the mercury in a stoneware dish or glass bottle, and shake about till the mercury is broken up and thoroughly brought into contact. Leave for 2–3 days, and then wash completely and repeatedly in clean water.

To remove metallic impurities, after redistillation, replace the mercury in the iron bottle, add nitric acid mixed with a double volume of water, and heat to 150° F. Leave the acid in the bottle for 24 hours, shaking well occasionally. Then drive off the water by gently heating the bottle. Remove the crust of nitrate of mercury, and wash *thoroughly* with clean water.

GOLD: *Chlorination by Plymouth Co.*

They treat 100 tons of concentrates per month of 30 days. The leaching occupies only 24 days in the month.

Table 109.—*Chlorination*: Expenses per month.

Roasting.

	\$	c.	\$	c.
3 men at \$2·50 a day for 30 days	225	00		
1¾ cords wood at \$4·25	223	13		
54 lb. salt at ¾ c.	12	15		
			460	28

Chlorine.

	\$	c.	\$	c.
60 lb. manganese per day at \$47 per ton	33	84		
68 lb. salt per day at \$15	12	24		
120 lb. acid per day at \$60	86	40		
			132	48

Leaching.

	\$	c.	\$	c.
40 lb. sulphuric acid for 24 days .. .. } 40 lb. sulphate of iron for 24 days .. .. }	57	60		
1 leacher at \$5·50 for 30 days	165	00		
Salary of foreman	125	00		
			347	60
			940	36

Or, per ton of concentrates, \$9·403.

At the Providence Mine are 2 roasting furnaces of the capacity of 9 tons in 24 hours. Each furnace requires 1 cord of wood in that time.

Table 110.—*Chlorination*: Cost per diem.

	\$	c.	£	s.	d.
1 foreman	3	00	0	12	0
1 white labourer	9	25	1	17	0
5 Chinamen at \$1·50	7	50	1	10	0
2 cords wood at \$5	10	00	2	0	0
29 lb. binoxide manganese at 2¾ c...	0	80	0	3	4
260 lb. salt at 1 c.	2	60	0	10	6
216 lb. sulphuric acid at 2 c.	4	32	0	17	6
Lime, sulphur, and calcium hyposulphite	0	30	0	1	3
Illuminating	0	20	0	0	10
Extras	1	00	0	4	0
Total	38	97	7	16	4

This makes the cost of treatment per ton of sulphurets 3·55 dols. (14*s.* 9*d.*) when the works are run at full capacity. But the ore contains about 7 per cent. of sulphurets, or 4⅓ tons in the 62 tons milled daily. This quantity of sulphurets does not keep the two furnaces running at full capacity, but both are in continual operation. Most of the expenses remain the same whether running at full capacity or not; the actual cost, therefore, figured on a working basis of 4⅓ tons daily capacity, approximates as in Table 111.

Table 111.—*Chlorination:* Cost per ton.

	\$ c.	£ s. d.
Labour	12 75	2 13 2
2 cords wood at \$5·00	10 00	2 1 7
14 lb. binoxide manganese at 2¾ c.	0 38	0 1 7
126 lb. salt at 1 c.	1 26	0 5 3
104 lb. sulphuric acid at 2 c.	2 08	0 8 8
Lime, sulphur, and calcium hyposulphite	0 15	0 0 8
Illuminating	0 20	0 0 10
Extras	0 50	0 2 1
Total per day	27 32	5 13 10
Adding to this the cost for milling per day	57 50	11 19 7
The total outlay per day equals	84 82	17 13 5

Or \$1·37 (5*s.* 8*d.*) per ton for extracting the gold and silver from the ore.

This estimate makes no allowance for the expenses of general supervision, interest on first cost, and gradual deterioration. The conditions of treatment in these works are, however, very special, and can hardly be considered as a basis for the general cost of treatment elsewhere.

Table 112.—GOLD: *Cost of Chlorinating* 5136 *tons of Sulphurets at Sutter Creek.*

Expense.	Total Amount.	Lb. per ton.	Cost per ton.	
	\$ c.		\$ c.	£ s. d.
Labour and superintendent's salary, at \$200 per month	39,339 00	..	7 66	1 11 11
82 tons peroxide of manganese, at \$40 per ton	3,280 00	32	0 64	0 2 8
128 tons salt, at \$15 per ton	1,920 00	50	0 38	0 1 7
308,160 lb. sulphuric acid, 66°, at 3½ c. per lb.	10,785 60	60	2 10	0 8 9
2568 cords of wood, at \$6 per cord	15,408 00	½ cord.	3 00	0 12 6
General expenses for 6 years, including assaying, repairing, sundry supplies, hose, tools, &c., insurance, taxes, water, new vats, interest on capital invested, repairs on furnace and buildings	19,003 20	..	3 70	0 15 5
Total expense	89,735 80	..	17 48	3 12 10

Table 113.—GOLD: *Chlorination; Cost by barrel process at Haile, South Carolina* (Thies).

Working on 4 tons daily.

	$ c.	£ s. d.
40 lb. lime chloride, at 3 c.	1 20	0 5 0
60 lb. sulphuric acid, at 2 c.	1 20	0 5 0
2 labourers, at 90 c.	1 80	0 7 6
1 chlorinator	2 0	0 8 4
Motive power	0 50	0 2 1
Sulphuric acid for making iron sulphate	0 12½	0 0 6
Repairs and wear	0 20	0 0 10
Total	$7 2½	£1 9 3

Or, $1 75 c. (7*s.* 4*d.*) per ton.

Table 114.—GOLD: *Chlorination; Cost at Bunker Hill.*

	$ c.	£ s. d.
Labour, per ton	4 75	0 19 9
Power and water	0 50	0 2 1
Wood, ⅝ cord at $6	3 75	0 15 8
30 lb. lime chloride, at 4 c.	1 20	0 5 0
36 lb. sulphuric acid, 66°, at 3½ c.	1 26	0 5 3
20 lb. salt, at ¾ c.	0 15	0 0 8
General expenses—assaying, melting, taxes, insurance, repairing, loss of material in handling, interest, &c.	3 00	0 12 6
Total	$14 61	£3 0 11

Table 115.—GOLD: *Chlorination; Estimated cost by Plattner Process.*

	$ c.	£ s. d.
Labour	4 00	0 16 8
Wood	3 00	0 12 6
Peroxide manganese	0 65	0 2 9
Salt	0 35	0 1 5
Sulphuric acid	2 00	0 8 4
Incidentals—taxes, insurance, ordinary repairs, iron sulphate, assaying material, &c.	3 00	0 12 6
Total	$13 00	£2 14 2

Table 116.—GOLD: *Lixiviation with Hyposulphites at Bertrand Mill.*

Labour per 24 hours for treating 50–60 tons.

		$ c.	$ c.	£ s. d.
Roasters—furnace men	2 at	4 00	8 00	1 12 0
„ —feeders	2 „	3 00	6 00	1 4 0
Driers and rollers	10 „	3 00	30 00	6 0 0
Cooling-floor	6 „	3 00	18 00	3 12 0
Leaching-floor, Chinamen	2 „	2 50	5 00	1 0 0
„ „ „	3 „	1 50	4 50	0 18 0
Rock breakers	2 „	3 00	6 00	1 4 0
Flue cleaners	4 „	1 50	6 00	1 4 0
Blacksmith	1 „	6 00	6 00	1 4 0
„ helper	1 „	3 00	3 00	0 12 0
Carpenters	2 „	5 00	10 00	2 0 0
Engineer	1 „	5 00	5 00	1 0 0
„	1 „	4 00	4 00	0 16 0
Fireman	1	2 50	2 50	0 10 0
Assayer	1	5 00	5 00	1 0 0
Lamp cleaner	1	1 50	1 50	0 6 0
Foreman	1	6 00	6 00	1 4 0
„	1	5 00	5 00	1 0 0
Office helper	1	1 50	1 50	0 6 0
General helper	1	3 00	3 00	0 12 0
Watchman	1	3 00	3 00	0 12 0
Woodmen, Chinamen	3	1 50	4 50	0 18 0
	1	3 00	3 00	0 12 0
			$146 50	£29 6 0

All the charging, discharging, and leaching are done by 4 Chinamen and 3 Irishmen. The total cost of milling the ore is 6·25 dols. (26*s.*) per ton. The cost of mining and delivering the ore at the mill is about 2·50 dols. (10*s.*), which makes the total cost about 9 dols. (36*s.*) per ton of actual expense on each ton of 30-oz. ore.

Table 117.—GOLD: *Roasting and Grinding Pyrites at Port Phillip.*

Cost per ton—	£ s. d.
Buddle expenses	1 1 8
Roasting—Labour, 13*s.* 3*d.*; fuel, 9*s.*	1 2 3
Grinding, labour	0 13 3
Mercury lost, 1 lb. 6¼ oz., value	0 4 3
Total cost per ton	3 1 5
Cost per oz. of gold obtained	0 13 2

Table 118.—GOLD: *Roasting and Grinding Pyrites at Walhalla.*

	s.	d.
Firewood	13	0
Wages	16	7
Repairs, cleaning flue, &c.	4	2
Per ton	33	9

Table 119.—GOLD: *Converting Percentages into Troy Weight per Statute Ton.*

Percentage.	Per ton. oz.	dwt.	gr.	Percentage.	Per ton. oz.	dwt.	gr.
0·0001	0	0	15·68	0·06	19	12	0
0·0002	0	1	7·36	0·07	22	17	8
0·0003	0	1	23·04	0·08	26	2	16
0·0004	0	2	14·72	0·09	29	8	0
0·0005	0	3	6·40	0·1	32	13	8
0·0006	0	3	22·08	0·2	65	5	16
0·0007	0	4	13·76	0·3	98	0	0
0·0008	0	5	5·44	0·4	130	13	8
0·0009	0	5	21·12	0·5	163	6	16
0·001	0	6	12·8	0·6	196	0	0
0·002	0	13	1·6	0·7	228	13	8
0·003	0	19	14·4	0·8	261	6	16
0·004	1	6	3·2	0·9	294	0	0
0·005	1	12	16·0	1·0	326	13	8
0·006	1	19	4·8	2·0	653	6	16
0·007	2	5	17·6	3·0	980	0	0
0·008	2	12	6·4	4·0	1306	13	8
0·009	2	18	19·2	5·0	1633	6	16
0·01	3	5	8·0	6·0	1960	0	0
0·02	6	10	16·0	7·0	2286	13	8
0·03	9	16	0·0	8·0	2613	6	16
0·04	13	1	8·0	9·0	2940	0	0
0·05	16	6	16·0	10·0	3266	13	8

Ex.—500 gr. ore gave 0·044 gr. gold, what is the yield per ton?

100 gr. of the ore will give 0·044 ÷ 5 = 0·0088 gr.; and

	Per cent.		oz.	dwt.	gr.
According to table	0·008	=	2	12	6·4
„ „	0·0008	=	0	5	5·44
So	0·0088	=	2	17	11·84 per ton.

Table 120.—GOLD: *Reckoner, by which the Value of any number of oz., dwt., and gr. may be readily calculated.*

At per oz.	Oz. 2	Oz. 3	Oz. 4	Dwt. 1	Dwt. 2	Dwt. 3	Dwt. 4	Dwt. 6	Dwt. 8	Dwt. 10	Gr. 1	Gr. 2	Gr. 3	Gr. 4	At per oz.
£ s. d.	£ s. d.	£ s. d.	£ s. d.	s. d.	s. d.	s. d.	s. d.	£ s. d.	£ s. d.	£ s. d.	d.	d.	d.	d.	£ s. d.
2 10 0	5 0 0	7 10 0	10 0 0	2 6	5 0	7 6	10 0	0 15 0	1 0 0	1 5 0	1¼	2½	3¾	5	2 10 0
2 12 6	5 5 0	7 17 6	10 10 0	2 7½	5 3¼	7 10¾	10 6	0 15 9¾	1 1 1	1 6 3	1¼	2½	3¾	5	2 12 6
2 15 0	5 10 0	8 5 0	11 0 0	2 9	5 6	8 3	11 0	0 16 6	1 2 0	1 7 6	1¼	2½	3¾	5	2 15 0
2 17 6	5 15 0	8 12 6	11 10 0	2 10½	5 9	8 7½	11 6	0 17 3	1 3 0	1 8 9	1¼	2½	3¾	5	2 17 6
3 0 0	6 0 0	9 0 0	12 0 0	3 0	6 0	9 0	12 0	0 18 0	1 4 0	1 10 0	1½	3	4½	6	3 0 0
3 12 0	7 4 0	10 16 0	14 8 0	3 7	7 2¼	10 9½	14 4¾	1 1 7	1 8 9½	1 16 0	1¾	3½	5¼	7	3 12 0
3 12 6	7 5 0	10 17 6	14 10 0	3 7½	7 3	10 10½	14 6	1 1 9	1 9 0	1 16 3	1¾	3½	5¼	7¼	3 12 6
3 13 0	7 6 0	10 19 0	14 12 0	3 7¼	7 3½	10 11¼	14 7	1 1 10¾	1 9 2¼	1 16 6	1¼	3½	5¼	7¼	3 13 0
3 15 0	7 10 0	11 5 0	15 0 0	3 9	7 6	11 3	15 0	1 2 6	1 10 0	1 17 6	1¾	3¾	5½	7½	3 15 0
3 15 3	7 10 6	11 5 9	15 1 0	3 9	7 6¼	11 3¼	15 0½	1 2 6¾	1 10 1	1 17 7½	1¾	3¾	5½	7½	3 15 3
3 15 6	7 11 0	11 6 6	15 2 0	3 9¼	7 6½	11 3¾	15 1	1 2 7¾	1 10 2¼	1 17 9	1¾	3¾	5½	7½	3 15 6
3 15 9	7 11 6	11 7 5	15 3 0	3 9¼	7 6¾	11 4¼	15 1¾	1 2 8½	1 10 3½	1 17 10½	1¾	3¾	5½	7½	3 15 9
3 16 0	7 12 0	11 8 0	15 4 0	3 9½	7 7	11 4¾	15 2¼	1 2 9½	1 10 4¼	1 18 0	1¾	3¾	5½	7½	3 16 0
3 16 3	7 12 6	11 8 9	15 5 0	3 9¾	7 7½	11 5¼	15 3	1 2 10½	1 10 6	1 18 1½	1¾	3¾	5½	7½	3 16 3
3 16 6	7 13 0	11 9 6	15 6 0	3 9¾	7 7¾	11 5½	15 3½	1 2 11¼	1 10 7	1 18 3	1¾	3¾	5½	7½	3 16 6
3 16 9	7 13 6	11 10 3	15 7 0	3 10	7 8	11 6	15 4	1 3 0¼	1 10 8¼	1 18 4½	1¾	3¾	5¾	7½	3 16 9
3 17 0	7 14 0	11 11 0	15 8 0	3 10	7 8¼	11 6½	15 4¾	1 3 1	1 10 9½	1 18 6	1¾	3¾	5¾	7½	3 17 0
3 17 3	7 14 6	11 11 9	15 9 0	3 10¼	7 8½	11 7	15 5¼	1 3 2	1 10 10¾	1 18 7½	1¾	3¾	5¾	7½	3 17 3
3 17 6	7 15 0	11 12 6	15 10 0	3 10½	7 9	11 7½	15 6	1 3 3	1 11 0	1 18 9	1¾	3¾	5¾	7¾	3 17 6
3 17 10½	7 15 9	11 13 7½	15 11 6	3 10½	7 9¼	11 8	15 6¾	1 3 4¼	1 11 1¾	1 18 11¼	1¾	3¾	5¾	7¾	3 17 10½
3 18 0	7 16 0	11 14 0	15 12 0	3 10¾	7 9½	11 8¼	15 7	1 3 4¾	1 11 2¼	1 19 0	1¾	3¾	5¾	7¾	3 18 0
3 18 3	7 16 6	11 14 9	15 13 0	3 10¾	7 9¾	11 8¾	15 7¾	1 3 5½	1 11 3¼	1 19 1½	1¾	3¾	5¾	7¾	3 18 3
3 18 6	7 17 0	11 15 6	15 14 0	3 11	7 10	11 9¼	15 8½	1 3 6½	1 11 4¾	1 19 3	1¾	3¾	5¾	7¾	3 18 6
3 18 9	7 17 6	11 16 3	15 15 0	3 11¼	7 10½	11 9¾	15 9	1 3 7½	1 11 6	1 19 4½	1¾	3¾	5¾	7¾	3 18 9
3 19 0	7 18 0	11 17 0	15 16 0	3 11¼	7 10¾	11 10	15 9½	1 3 8¼	1 11 7	1 19 6	1¾	3¾	5¾	7¾	3 19 0
3 19 3	7 18 6	11 17 9	15 17 0	3 11½	7 11	11 10½	15 10	1 3 9¼	1 11 8¼	1 19 7½	1¾	3¾	5¾	7¾	3 19 3
3 19 6	7 19 0	11 18 6	15 18 0	3 11½	7 11¼	11 11	15 10¾	1 3 10	1 11 9¼	1 19 9	1¾	3¾	5¾	7¾	3 19 6
3 19 9	7 19 6	11 19 3	15 19 0	3 11¾	7 11½	11 11¼	15 11¼	1 3 11	1 11 10¼	1 19 10½	1¾	3¾	5¾	7¾	3 19 9
4 0 0	8 0 0	12 0 0	16 0 0	4 0	8 0	12 0	16 0	1 4 0	1 12 0	2 0 0	2	4	6	8	4 0 0

Table 121.—*Quantity of Fine Gold in 1 oz. of any alloy to $\frac{1}{8}$ Carat, and the Mint Value of the Gold in 1 oz. of each Alloy.*

Fine Gold.			Carat Gold.			Sterling Value.		
oz.	dwt.	gr.	carats.	gr.	eighths.	£	*s.*	*d.*
1	0	0	24	0	0	4	4	11·454
0	19	4	23	0	0	4	1	4·977
0	18	8	22	0	0	3	17	10·500
0	17	12	21	0	0	3	14	4·023
0	16	16	20	0	0	3	10	9·545
0	15	20	19	0	0	3	7	3·068
0	15	0	18	0	0	3	3	8·590
0	14	4	17	0	0	3	0	2·113
0	13	8	16	0	0	2	16	7·636
0	12	12	15	0	0	2	13	1·159
0	11	16	14	0	0	2	9	6·682
0	10	20	13	0	0	2	6	0·204
0	10	0	12	0	0	2	2	5·727
0	9	4	11	0	0	1	18	11·250
0	8	8	10	0	0	1	15	4·773
0	7	12	9	0	0	1	11	10·295
0	6	16	8	0	0	1	8	3·818
0	5	20	7	0	0	1	4	9·341
0	5	0	6	0	0	1	1	2·863
0	4	4	5	0	0	0	17	8·386
0	[illegible]	8	4	0	0	0	14	1·909
0	[illegible]	12	3	0	0	0	10	7·432
0	[illegible]	16	2	0	0	0	7	0·954
0	[illegible]	20	1	0	0	0	3	6·477
0	[illegible]	15	0	3	0	0	2	7·858
0	0	10	0	2	0	0	1	9·239
0	0	5	0	1	0	0	0	10·619
0	0	4·375	0	0	7	0	0	9·292
0	0	3·750	0	0	6	0	0	7·964
0	0	3·125	0	0	5	0	0	6·637
0	0	2·500	0	0	4	0	0	5·309
0	0	1·875	0	0	3	0	0	3·982
0	0	1·250	0	0	2	0	0	2·655
0	0	0·625	0	0	1	0	0	1·327

	£	*s.*	*d.*
1 oz. pure gold is worth	4	4	11
1 dwt. " "	0	4	3
1 gr. " "	0	0	2

Ex.—If a sample of bullion is 20 carats 3 gr. 5 eighths, how many troy dwt. and gr. are there in it, and what is the value of the gold in the alloy?

According to table

	dwt.	gr.	£	*s.*	*d.*
20 carats .. .. =	16	16 .. .. =	3	10	9·545
3 grains .. .. =	0	15 .. .. =	0	2	7·858
5 eighths .. .. =	0	3·125 .. .. .. =	0	0	6·637
Answer	17	10·125	3	14	0·040

GOLD.—*Refining Bullion.* (Sage.)

(1) *Inquartation and Granulation of the Bullion.*—The gold and silver are sent from all parts of the country, consisting of bullion, amalgams, plate, &c. These are melted and assayed, and are then turned over to the melter and refiner. The bullion is again melted in a large graphite crucible, the charge being made up so that the gold shall not exceed the $\frac{1}{3}$, nor the copper $\frac{1}{12}$ part of the entire weight. When the metal is melted and thoroughly mixed, it is granulated by pouring, with a peculiar rotatory motion, into a cylindrical iron tank, 3 ft. high by 3 ft. diameter, filled with cold water, and supplied with a copper colander, which, when the charge is all granulated, is raised by means of an iron crane, the water nearly all running off. It is then poured on an inclined iron table to allow the rest of the water to drain off.

(2) *Solution of the Granulations.*—The pots used for parting the alloy are made of cast iron, $3\frac{1}{2}$ ft. and 2 ft. in diameter, by 3 ft. and 2 ft. in depth, and are set on brick fireplaces. There are 4 pots holding 160 gal., and 3 holding 50 gal. Each pot is covered with a funnel-shaped hood of sheet lead, with an opening slid[illegible]r, through which the charge is introduced, and which [illegible]g door. From each of these hoods a flue leads to the [illegible]ing chambers on the floor above; from the last of these a lon[illegible]ing leaden flue leads into the stack. Both chambers have platforms on which coke is laid several feet in thickness (through which the fumes pass, and are condensed), and are supplied with water sprinklers, so that a spray of water is continually cooling the atmosphere. Nitrous fumes are furnished by soda nitrate, acted upon by sulphuric acid.

About 300 lb. of the granulations are put in each of the larger pots, with about 650 lb. sulphuric acid, and 250 lb. more of the acid is gradually added during 3 hours' boiling. The resulting solution is then siphoned off into the receiving vats on the floor below. The fire being withdrawn, a partial charge of acid is added, and the gold residue is taken out by means of a perforated iron ladle, placed in two of the smaller pots, and boiled for 6 hours with 3 successive charges of about 300 lb. of acid. It is then placed in the third pot and boiled twice. The acid from the last 5 boilings is poured or run off into reservoirs on the floor, and is used again as a portion for fresh granulations. The gold is then placed in a tub, and washed once with cold, and twice with warm water; this water is poured into the washing-tub, from which, on settling, the solution is run into a large tank on the floor below.

(3) *Treatment of the Gold Residue.*—The gold is now emptied into one of the filters, washed thoroughly with warm water till it becomes "sweet," drained, boiled in 2 charges of acid for 4 hours, and again washed and sweetened. When it is desired to make very fine metal this process is repeated. It is then thoroughly drained and caked by a hydraulic press.

Refining—continued.

(4) *Melting and Refining the Gold.*—After the gold residue is pressed into cakes, these are placed in an oven and dried, then taken to the melting room, where they are broken up and placed in a graphite crucible, fluxed for 3–5 hours, and run into bars, varying from 997½ to 998½ thousandths in fineness.

(5) *Reduction of the Silver.*—There are for this operation 4 reducing vats, 2 concentrating vats, 8 crystallising vats, and 3 filters, 2 ft. 9 in. diameter by 19 in. deep, with a space below; 2 tanks on a high platform receive the washings from the gold. The sizes of the reducing, concentrating, and crystallising vats vary, on account of having to accommodate them to a given space. The vats and tanks are made of wood, and lined with heavy sheet lead. The reducing and concentrating vats are heated by a system of coils of lead pipe, through which steam passes. These vats are inclosed, and connect by a flue with the stack.

Before the silver sulphate is run into the vats, ingots or bars of copper are placed on end around the sides and bottoms, next to the heating coils. The solution is then run in. A sufficient amount of water, together with the weak solution obtained in washing the gold, is added to reduce the strength of the solution to 15°–25° B., which has been found to facilitate the reduction. The sulphuric acid leaving the silver to attack the copper, the silver is precipitated or deposited as metallic silver. It requires 5–6 hours' boiling to complete the reduction.

The resulting copper solution is run off through a filter into a concentrating vat. The silver remaining on the copper bars is scraped off, and the whole is put into a filter. Copper hoes and shovels are used in the handling of the silver. About 2 hours' washing with warm water is required to "sweeten" the silver. It is then put into the draining boxes, made into cakes by a hydraulic press, and dried in an oven similar to that used for gold. When silver containing little or no gold is operated upon, 350 lb. of granulations are dissolved in one pot. With baser metals, the charge of granulations is reduced, copper requiring much more acid to dissolve it than silver.

(6) *Melting and Refining the Silver.*—The cakes are broken up, placed in graphite crucibles, and fluxed with soda nitrate, borax, bone ash, and a little soda ash. These reagents absorb the little base metal which remains, as sulphate, in washing. From 4 to 6 hours are required for fluxing. The silver is then cast into bars of 998½ to 999½ thousandths fine.

(7) *Treatment of the Sulphate of Copper.*—The solution of copper being run into the concentrating vats, is boiled until it reaches the strength of 40° B. and run into crystallising vats. In several days crystals are formed, and the mother-liquor is run into a large tank on the floor below, and thence into the carboys or tanks of purchasers. The crystals of copper sulphate are taken from the sides and bottom of the vats, drained, dissolved in water, and run

Refining—continued.
back into the crystallising vats at a strength of 32°-34° B. The copper sulphate again crystallises, and the mother-liquor is put back into the concentrating vats. The crystals are then taken from the vats, dried, put into barrels, and sold.

If lead is present to any extent in the bullion, it is removed by cupellation before granulating.

The consumption of copper is greatly economised in the reduction of silver by melting silver deposits free from gold and under 400 fine with the copper used for that purpose. The silver in them is thus obtained pure, without a direct parting, the copper alloy taking the place of that amount of the purchased metal that would otherwise be used.

The proceeds of the sale of copper sulphate crystals, and the liquor, nearly cover the total expense of the acid and bar copper bought.

All wood, after it becomes useless, is burnt; old, unserviceable crucibles are broken up and ground. The grains obtained from them are melted and treated as before, then put through a rough washing and amalgamation process; the resulting tailings are dried, assayed, barrelled, and sold to sweep smelters.

GOLD MILLS.

Specifications for 10-stamp Mill for Working Free-milling Ore.
(Fraser and Chalmers, Limited.)

Breaker, Grizzly, and Feeders.

1 Blake eccentric pattern improved crusher, 10 × 7, all complete.

1 grizzly, or ore screen, about 4 × 10, made from 2 × $\frac{3}{4}$ iron, with washers between to make opening about 2 in., rods to connect bars, with nuts for same.

2 Tulloch automatic feeders, complete, with wood frames and sheet iron hoppers.

All necessary track iron and wood screws for track for feeders to run upon.

Stamps.

1 10-stamp mill of 850 lb., each stamp of improved design, arranged to run in one battery of 10 stamps, by belt and tightener from stamp countershaft.

2 high mortars or batteries, each about 5000 lb. weight, planed upon bottom and for screen frames, foundation bolt-holes drilled by template, mortars arranged inside for receiving copper lining front and back.

2 hard wood screen frames fitted to mortars.

4 wrought iron keys for holding screen frames in place.

2 Russia iron slot punched screens, of such size as may be required.

10 patent stamp shoes, made from white iron, with soft grey iron necks.

10 dies, of best quality white iron.

10 heads, bored for stems and recessed for shoe stem.

10 stems, both ends tapered, made from best refined iron. Ends being tapered, when one end breaks the stem can be reversed and other end used.

10 tappets with wrought jib and steel keys, all properly fitted to place.

10 cams (5 right and 5 left hand) fitted to cam shaft with steel keys, all properly marked to place, to give proper drop.

1 heavy hammered iron cam shaft turned full length and key-seated for pulley and cams.

2 wrought collars and steel set screws, fitted to cam shaft.

3 heavy corner cam shaft boxes, babbitted and bored, planed upon back, and furnished with bolts and caps.

2 Jack shafts, not turned.

4 Jack shaft boxes.

Specifications—continued.

10 iron sockets for wood levers, lined with leather.

10 wood levers or finger pieces, for holding up stamps, fitted to sockets.

1 pair of double sleeve flanges for wood pulleys, turned and fitted together, with wood work built up, hub key seated, wood work turned up and painted, and securely bolted through flanges.

All bolts, rods, nuts, and washers, for 10-stamp frame work complete, including all holding-down bolts and washers for mortars.

1 complete set of hardwood guide boxes, all worked out for stamp stems, with all guide bolts, nuts and washers.

2 pieces of rubber packing, $\frac{1}{4}$ in. thick, for top of mortar blocks, for mortars to rest upon.

Water Pipes.

1 complete set of water pipes for 10 stamps proper, with valves and fittings ready for connection with main supply, also hose for washing copper plates in front of mill.

Copper.

2 sheets of pure L. S. copper, 96 in. by width of mortar by $\frac{1}{8}$ in., for tables in front of mill.

2 sheets of pure L. S. copper, $\frac{3}{16}$ in., for mortars inside, all fitted, front and back.

2 sheets of pure L. S. copper, $\frac{3}{16}$ in., for mortars inside, all fitted, sides.

Building Bolts.

1 complete set of building bolts, rods, nuts, and washers, for frame of building, and also for ore bins.

Tighteners.

1 stamp tightener for stamp belt, complete, with wood frame, rack, pinion, hand wheels, dogs, etc.

1 breaker tightener for breaker belts, complete, with swinging frame, chain, shaft, and hand wheel.

1 main tightener for engine belt, complete, with wood frame, rack, pinion, hand wheel, dogs, etc.

Shafting, Pulleys, and Belting.

1 main line turned shaft, $3\frac{3}{8}$ in. dia. by 11 ft. 3 in.

3 pillow blocks for $3\frac{3}{8}$ in. shaft.

1 pulley, 32 in. by 15 in., to drive stamps.

1 pulley, 42 in. by 14 in., on engine shaft, to drive main line shaft.

All necessary bolts for pillow blocks.

All necessary collars and set screws.

1 turned shaft, $2\frac{3}{8}$ in. by [illegible] ft. 6 in., for driving crusher.

2 pillow blocks for $2\frac{3}{8}$ in. shaft.

Specifications—continued.

1 pulley, 60 in. by 14 in., to receive power from engine.
1 pulley, 36 in. by 10 in., to drive crusher countershaft.
1 pulley, 24 in. by 10 in., on crusher countershaft.
1 pulley, 40 in. by 8 in., to drive crusher.
All necessary bolts for pillow blocks.
All necessary collars and steel set screws.
1 rubber belt, 45 ft. by 14 in., 4-ply, for battery.
1 belt, 49 ft. by 14 in. by 4-ply, for engine.
1 belt, 70 ft. by 10 in. by 4-ply, for crusher countershaft.
1 belt, 47 ft. by 7 in. by 4-ply, for crusher.
1 belt, 27 ft. by 5 in. by 3-ply, for engine belt feed pump.
1 hide of lace leather.

Amalgam Safe.

1 amalgam safe and strainer, with padlock.

Retort and Bullion Furnace.

1 retort, complete, with cover, wedge and condenser.
1 16-in. bullion furnace, with all iron work, one set of crucible tongs, 2 gold bullion moulds, and one set of steel letters for stamping bullion.

Overhead Crawl and Block.

1 overhead carriage crawl and track iron, with wood screws for same.
1 one-ton differential pulley block.

Engine.

1 Fraser and Chalmers' stationary slide valve steam engine, cylinder 9 in. bore by 14 in. stroke, complete, as per specifications attached. [This engine has power for driving the above described machinery only, together with two or four frue vanners if required.]

Boiler.

1 Fraser and Chalmers' tubular steam boiler, 40 in. dia. by 10 ft. long, complete with all fixtures and trimmings, breeching and smoke stack, as per our standard specifications attached.

Feed Pump, Heater, and Pipes.

1 belt feed pump, 2 by 3.
1 heater, with pipe coil.
All pipes, valves, and fittings for steam, water, and exhaust to make power complete, as per plans we furnish.
Total approximate weight 60,000 lb.

N.B.—To the above on most gold ores must be added for concentrating the sulphurets eight frue vanning machines, with amalgam savers and all necessary shafting, pulleys, and belts, for driving the same. This will increase the weight of mill to say 85,000 lb.

SILVER MILLS.

Specifications for 10-stamp Wet Crushing Mill. (Fraser and Chalmers, Limited.)

Crusher.

1 10 by 7 in. Blake crusher, to be furnished complete ready to run when set in place.

1 duplicate set of jaw plates for above crusher.

Grizzly.

1 grizzly or ore screen for relieving breaker, size 4 by 10 ft. complete.

Automatic Feeders.

2 Tulloch improved automatic feeders complete, with wood frames and sheet iron hoppers. All necessary track iron, punched and countersunk with wood screws for laying same for feeders to operate upon.

Stamps.

1 10-stamp mill of improved design, each stamp weighing 850 lb., arranged to run in one battery of 10 stamps by belt and tightener from stamp countershaft, complete in detail as below.

2 high mortars or batteries, double discharge, all to be complete with screen frame and faces planed; also planed upon bottom for resting upon foundation. The bolt holes drilled by template

4 hard wood screen frames fitted to mortars.

8 wrought iron keys for holding screen frame in place.

4 Russia iron slot punched screens, of such size as may be required.

10 patent stamp shoes, made from white iron, with soft grey iron necks.

10 stamp dies of best quality white iron.

10 stamp heads, bored for stems, and recessed for shoe stem.

10 stamp stems, made from extra fine iron, both ends tapered; when one end breaks the stem can be reversed and other end used.

10 stamp tappets, with wrought iron jib and steel keys all properly fitted to place. Tappets faced on ends.

10 cams (5 right and 5 left hand) fitted to cam shaft with steel keys all properly marked to place to give proper drop.

1 heavy hammered iron cam shaft, turned full length, key-seated for cams and driving pulley.

2 wrought iron collars with steel set screws, fitted to cam shaft.

3 heavy cam shaft boxes, babbitted, hammered and bored, planed upon back, and furnished with bolts and caps.

Specifications—continued.

2 Jack shafts, not turned.

4 chairs or sockets for jack shafts to rest in.

10 iron sockets for wood levers, lined with leather, for stamp holders.

10 wood levers or finger pieces for holding up stamps, fitted to sockets.

1 pair of double sleeve flanges for wood pulley, turned and fitted together with wood work built up between, hub key-seated, wood work turned up and painted and securely bolted through flanges, to be fitted with steel key, properly marked to place.

All necessary bolts, rods, nuts, and washers for 10-stamp framework complete, including all holding-down bolts and washers for mortars.

1 complete set of hard wood guide boxes, all worked out for stamp stems, with all guide bolts, nuts, and washers.

2 pieces of rubber packing $\frac{1}{4}$ in. thick, for top of mortar blocks for mortars to rest upon.

Water Pipes.

1 complete set of water pipes for 10-stamp mill, including all valves, water cocks, and fittings for supplying each stamp with water. Connection to be prepared to receive water from main supply.

Memorandum.

The piping actually furnished does not include sufficient to connect with main supply, as quantity cannot be determined upon owing to not knowing location of water tank.

Combination Pans.

4 improved combination amalgamating pans, each 5 ft. diameter, with wood staves, to be furnished with upright cone in bottom, upright spindle fitted with separate steel toe, 2 hand wheels and screw on top of spindle for raising muller nut for screw, driver sleeves, driver arms separate from sleeves and bolted to same muller plate. 8 cast iron shoes and 8 cast iron dies to each pan, wrought iron bands and lugs for staves, step box fitted on plate, which also carries one bearing of countershaft, step box fitted with steel buttons and bushings, countershaft, driving pulley, out end bearing for shaft. All bolts for boxes for bolting to framework.

Settlers.

2 8-ft. combination settlers complete, the same in detail as pans enumerated above, with the exception of shoes and dies. Wooden shoes to be furnished with settlers.

Clean-up Pan.

1 48-in. clean-up pan, all complete as usually furnished, the same as pans detailed above.

Specifications—continued.

Retort.

1 12-in. silver retort, all complete, with cover bar and hand screw for holding cover in place, carriers, fire front complete, with fire door and liners, dead plate, back bearer, double grate bars, condensing pipe, cast iron ash pan, all necessary wall binders and rods for bracing brick work.
1 set of castings for 16-in. bullion furnace complete, including top cover, bearing bars, grate bars, anchor bolts, &c.
6 assorted black lead crucibles and covers.
1 set of trays or cups for holding amalgam.
1 pair crucible tongs.
1 set of bullion moulds, three in number, assorted sizes.
1 set of steel numbers for stamping bullion bars.
1 iron floor plate, punched and countersunk, with wood screws for laying same for retort room floor.
1 smoke stack for retort bullion furnace, of suitable diameter and length, with base plate and guys for staying stack.

Quicksilver System.

1 complete quicksilver elevator, with rubber belt, Russia iron cups, and all fixtures and fittings required for making elevator complete, including:
1 upper and lower quicksilver tank.
2 quicksilver charging pots.
All pipes, iron cocks, and fittings for the complete quicksilver circulating system that may be required to make same complete.

Overhead Crawls.

3 overhead carriage crawls complete.
2 two-ton differential pulley blocks.
1 one-ton differential pulley block.
All necessary track iron, punched and countersunk, with wood screws for laying same for overhead crawls to run upon.

Piping.

All necessary water pipes, valves and fittings for the complete mill, for supplying pans and settlers with the necessary steam and water, ready to receive connection with main supply.

Tighteners.

1 crusher tightener complete.
4 pan tighteners complete.
1 stamp tightener complete.

Shafting, Pulleys, and Belting.

All necessary shafting, pulleys, boxes and belting for driving all of the above described machinery in accordance with our drawings.
All the belting throughout the entire mill to be Boston Belting Company's best brand.

Specifications—continued.

All pulleys to be turned, faced, and balanced, pillow blocks to be planed upon bottom and lined with best babbit metal and bored out, couplings to be fitted to shaft with keys, to be turned and faced, all bolts to be furnished for all bearings, all key-seats to be cut in shafts so as not to be in bearings.

Building Bolts.

All necessary bolts, rods, nuts, and washers for the complete framework of mill building in accordance with our drawings as usually furnished.

Engine.

1 Fraser and Chalmers' slide valve engine with Corliss style frame, size 14 by 24 in., all complete in detail as per printed specifications attached.

Boilers.

2 Fraser and Chalmers' tubular steam boilers, each 48 in. diam. by 14 ft. long, complete in detail as per printed specifications attached.

Heater.

1 24-in. tubular steam heater complete, including galvanised iron pipe for passing through roof.

1 No. 3 Knowles' steam boiler feed pump.

All necessary pipe connections for properly connecting engine, boiler, heater and feed pump.

Total Approximate Weight, 175,000 lb.

Specifications for 10-stamp Dry-crushing Chloridising Mill.

(Fraser and Chalmers, Limited.)

Boilers.

2 Fraser & Chalmers' tubular steam boilers. each 48 in. diam. by 14 ft. long, all complete as per specifications attached.

1 Fraser & Chalmers' Corliss steam engine, size 14 by 42 in., all complete in detail as per specifications attached. Crank shaft to be fitted with suitable size clutch coupling for coupling to pan line shaft.

1 Fraser & Chalmers' tubular steam heater, 24 in. diam., all complete in every respect.

1 No. 4 Knowles' boiler feed pump for feeding boilers with water.

All necessary steam, exhaust, and feed pipes to properly connect boilers, engine, heater, and feed pump.

Grizzly.

1 Grizzly or ore screen for relieving crusher, size 4 by 10 ft.; made from 2 by 1 in. iron with washers between. Rods to connect bars with nuts for same.

Specifications—continued.

Crusher.

110 by 7 Blake crusher, all complete ready to run when set in place.

Automatic Feeders.

2 Tulloch automatic ore feeders for stamps, with wood frames and sheet iron hoppers.

All necessary track iron, punched and countersunk, with wood screws for laying same for feeders to operate upon.

Stamps.

1 10-stamp mill of improved design, each stamp weighing 900 lb., arranged to run in one battery of 10 stamps by belt and tightener from stamp countershaft, all complete in detail as below:—

2 high mortars, double discharge, planed upon bottom, and faced for screen frames. Foundation bolt holes drilled by template.

4 wood screen frames, fitted to mortars.

8 wrought iron keys for holding screen frames in place.

4 brass wire cloth screens of such size as may be required.

10 patent stamp shoes.

10 patent stamp dies.

10 stamp heads, bored for stems and recessed for shoe stem.

10 stamp stems, made from extra refined iron, both ends tapered; ends being tapered, when one end breaks the stem can be reversed and other end used.

10 tappets with wrought iron jibs and steel keys, all properly fitted to place. Faces turned.

10 cams (one-half right and one-half left hand), fitted to cam shaft with steel keys all properly marked to place to give proper drop.

1 heavy hammered iron cam shaft, turned full length and key-seated for pulley and cams.

2 wrought iron collars with steel set screws, fitted to cam shaft.

3 heavy corner cam shaft boxes, babbitted and bored, planed upon back and bottom, and furnished with bolts and caps. Boxes to be babbitted with best composition metal.

2 Jack shafts, not turned.

4 Jack shaft boxes.

10 iron sockets for wood levers, lined with leather.

10 wood levers or finger pieces for holding up stamps, fitted to sockets.

1 pair of double sleeve flanges for wood pulley, turned and fitted together with wood work built up between, hubs key-seated, wood work turned up, painted and securely bolted through flanges.

Specifications—continued.

All necessary bolts, rods, nuts, and washers for 10 stamp frame work complete, including all holding-down bolts and washers for mortars.

1 complete set of hard wood guide boxes for 10 stamps, all worked out for stamp stems, with all guide bolts, nuts, and washers.

4 sheets of rubber packing, each $\frac{1}{4}$ in. thick, for top of mortar blocks for mortars to rest upon.

Roasting Furnace.

1 improved Howell-White roasting furnace, 52 in. diam., at small end, 62 in. diam. at large end, by 27 ft. long, made in 8 sections, $\frac{3}{4}$ in. thick; sections faced and bolted together with $\frac{5}{8}$ in. bolts, with all fixtures and fittings necessary to make the furnace complete in every respect as usually furnished, including carrying rollers, gearing, pulleys, vertical shafting, fire front, grate bars, &c.

1 smoke stack 42 in. diameter by 60 ft. long.

400 ft. $\frac{3}{8}$ in. guy rope.

1 base plate for stack.

1 set of fire tools for the above furnace.

Revolving Dryer.

1 revolving dryer made of cast iron, 44 in. diam. at large end, $36\frac{7}{8}$ in. diam. at small end, by 18 ft. long, made in sections, all properly turned and faced, drilled and bolted together with $\frac{5}{8}$ in. bolts; dryer to be furnished complete with fire front, grate bars, bearings, binding bars, tie rods, gearing, boxes, truck wheels, sole plates for bearings, countershafts, tight and loose pulleys, and everything necessary to make dryer complete in all respects.

1 smoke stack for dryer, 24 in. diam. by 50 ft. long.

300 ft. of $\frac{5}{8}$ in. galvanised iron guy rope.

1 cast iron base plate for smoke stack.

Feeder for Dryer.

1 Tulloch ore feeder for feeding dryer from ore bins, to be furnished complete with countershaft and pulleys.

All necessary track iron, punched and countersunk, with wood screws for laying same for feeder to operate upon.

Sheet Iron Shute.

1 sheet-iron shute from dryer to self-feeders at stamps.

Pans.

4 improved combination amalgamating pans, each 5 ft. diam., with wood staves, to be furnished with upright cone in bottom, upright spindle, fitted with separate steel toe, 2 hand wheels and screw on top of spindle for raising muller nut for screw

Specifications—continued.

driver sleeves, driver arms separate from sleeves and bolted to same, muller plate, 8 cast iron shoes and 8 cast iron dies to each pan, wrought iron bands and lugs for staves, step box fitted on plate, which also carries one bearing of countershaft; step box to be fitted with steel buttons and bushings, countershaft, driving pulley, out end bearing for shaft, all bolts for boxes and for bolting to framework.

Settlers.

2 8-ft. improved combination settlers, with wood staves, to be complete in every respect as pans above, the enumeration being the same excepting shoes and dies, wooden shoes and dies being furnished for the settlers.

Clean-up Pan.

1 30-in. clean-up pan with iron sides, complete in every respect. Fitted with cone pulley for changing speed.

Ore Bin Gate.

1 ore gate complete for ore bins, with rack, hand wheel, slide and plate.

Ore Gate for Dryer Pit.

1 ore gate complete for dryer pit, with rack, hand wheel, slide and plate.

Retort.

1 14-in. silver retort complete, including cover, bar and nut, screw for holding cover in place, 3 retort carriers, fire fronts complete, with doors and liners, dead plate, back bearers, 2 double grate bars, condensing pipe, cast iron ash pan, wall binders and rods for bracing brick work, and all necessary fittings required for the complete erection.

Bullion Furnace.

1 set of castings for 16 in. bullion furnace top, including cover, bearing bars, grate bars, anchor bolts, and all fixtures and fittings belonging thereto.
6 assorted black-lead crucibles and covers.
1 set of trays or cups for holding amalgam.
1 pair of crucible tongs.
2 1000-ounce bullion moulds.
1 500-ounce bullion mould.
1 set of steel numbers for stamping bullion bars.
1 smoke stack for retort bullion furnace, 20 in. diameter by 30 ft. long, with base plate and guy ropes for staying same.
1 set of iron floor plates for retort room floor, with all necessary screws for laying same.

Overhead Crawls.

3 overhead carriage crawls complete.

Specifications—continued.

Pulley Blocks.

2 two-ton Yale & Towne differential pulley blocks, with endless chain.

1 one-ton Yale & Towne differential pulley block, with endless chain.

160 ft. $1\frac{1}{2}$ by $\frac{1}{4}$ in. track iron, punched and countersunk, with wood screws for laying same.

Battery Conveyors.

2 battery conveyors with 8 in. flights, each conveyor 16 ft. long, to be furnished complete with shafts, pulleys, pillow blocks, and collars.

Roaster Conveyors.

3 roaster conveyors with 10 in. flights, each conveyor 16 ft. long, to be furnished complete with pulley, chain, wheels, and bearings.

QUICKSILVER SYSTEM.

Elevator.

1 complete quicksilver elevator, with rubber belts, Russia iron cups, and all fixtures and fittings required for making elevator complete in every respect.

1 each upper and lower quicksilver tanks.

2 quicksilver charging pots for pans, size 12 by 12 in.

2 amalgam safes with strainers complete, with padlocks and duplicate keys, with all necessary fittings and fixtures to make same complete.

1 amalgam car, complete.

120 ft. one-half round track iron, with spikes for laying same for car to operate upon.

Quicksilver Piping.

All pipes, iron cocks and fittings for the complete quicksilver circulation system that may be required in accordance with our drawings and necessary to make system complete in every detail.

Tighteners.

1 main tightener for 16-in. belt, to be furnished complete with pulley, boxes, screws, hand wheel, nuts, and frames.

4 pan tighteners for 12-in. belt, with improved angle iron frames, shafts, pulleys, wrought iron yokes, chains, upright shafts, step and guide boxes, hand wheels, and plates.

1 crusher tightener for 7-in. belt, with pulley, boxes, shaft, step, pinion, ratchet, plate, dog and hand wheel, rack, wood frame, and bolts.

Specifications—continued.

Dust Pipes.

1 complete set of galvanised iron dust pipes for removing dust from battery.

Exhaust Fan.

1 Sturtevant monogram exhaust fan of suitable size, with countershaft complete for above dust pipes.

Water Pipes.

All water pipes, valves, and fittings, necessary for the complete mill, for supplying pans and settlers with necessary steam and water, ready for receiving connection with main water supply, but not including pipe for connecting with tank or mill supply.

1 hot ore car, complete, made entirely of iron.
2 ½-ton scoop ore cars, with iron bodies, 18 inch gauge.
1 set of iron work for transversal car, with axles and wheels.
180 ft. of 12-lb. T-rail, with spikes and joints for laying same for cars to run upon.
All necessary bolts, rods, nuts, and washers for the complete frame work of mill building, in accordance with our drawings as usually furnished by us.
7 complete sets of ore gates for pulp bins, with levers, slides, and plates.

Elevators.

1 ore elevator complete, comprising:
1 shaft, 2 15/16 by 5 ft.
2 pillow blocks, 2 15/16 in.
2 pulleys, 36 by 8½ in.
1 shaft. 2 7/16 in. by 2 ft. 6 in.
2 pillow blocks, 2 7/16 in.
1 pulley, 16 in. by 8½ in.
All necessary collars, bolts, and steel set screws.
88 7-in. Due's heavy elevator buckets.
176 bolts for attaching buckets to belt.
125 ft. 8 in. 5-ply endless rubber belt for elevator, belt punched with holes for attaching buckets.

Shafting, Pulleys, and Boxes.

All necessary shafting, pulleys, boxes and belting for driving all of the above described machinery, in accordance with our drawings.
An assortment of copper rivets and burrs.

Total approximate weight, 265,000 lb.

Specifications—continued.

Addenda.

Smoke Stacks.

In the above estimates we have included smoke stacks for both roasting furnace and revolving dryer. If, however, it is desired to build stacks of brick, omit the smoke stacks we have included. Brick stacks are only practicable in some localities, and it will be found that iron stacks such as we have included are the cheapest, being much more easy to erect. Stacks rolled, punched, and shipped K. D., in crates when desired ; usually shipped in riveted sections of 20 ft.

Fire-brick for Roasting Furnace.

For lining the 60-in. Howell-White roasting furnace, 3040 special shaped fire-bricks are required. Sometimes this fire-brick can be purchased near the mines. If, however, it is desired to have this brick shipped with the machinery, we give below the cost and weight.

3040 special shaped fire-bricks, weight about 36,500 lb., cost about 310 dols., F.O.B. cars, Chicago.

For this amount of fire-brick, you would require about two barrels of fire-clay, each costing 4 dols., weighing 500 lb. each.

The mill, as covered by specifications, is complete and automatic.

We recommend the use of patent sectional stamp guides instead of ordering guides as specified above.

GOLD AND SILVER MILLS.

Combination Process. (Fraser and Chalmers, Limited.)

In many so-called free milling ores of silver, or silver and gold combined, there are small quantities of sulphides of the baser metals, not sufficient in quantity or value to make the ore suitable for roasting, yet preventing a high extraction by free milling, besides increasing the cost of the same. Such ores are most economically treated by a combined process of concentration and amalgamation ; the usual method being to stamp wet—over copper plates if gold is present—concentrate on frue vanners, and then amalgamate the tailings in pans, preferably by the Boss continuous system. The effect of this treatment is as follows:—the free gold is caught at once on the copper plates, the sulphurets are saved as a rich product, by the concentrators for subsequent treatment, and the residue is in good shape then for amalgamation in pans. The benefits to amalgamation, by first abstracting the sulphurets, are evident as shown—

(a) Grinding in the pans is lessened or entirely dispensed with, so decreasing wear of castings and fuel consumption.

(b) Loss of quicksilver is decreased.

(c) Coarser crushing, and therefore increased capacity of stamps, becomes possible.

(d) Bullion of a higher grade is obtained.

(e) The total percentage of extraction is raised.

All these advantages are quite obvious, and may, together constitute the difference between a good profit and an actual loss, in working some low grade ores. The Montana Company (Ltd.), by the adoption of this process, obtained a total increased saving over simple pan amalgamation, of from 8 dols. to 10 dols. per ton, decreased the loss of quicksilver by $\frac{3}{4}$ lb. per ton of ore, and brought the grade of the bullion from 500 fine up to 900 fine.

The cost of this process is from 3 dols. to 7 dols. per ton, saving from 75 to 85 per cent.

COPPER SMELTING PLANT.

Hardware Tools and Miscellaneous Supplies required for a 30-ton Plant
(Fraser and Chalmers, Limited.)

HARDWARE.

- 4 iron wheelbarrows.
- 6 L. H. square point shovels.
- 1 mason's trowel.
- 1 No. 7 26-in. hand saw.
- 1 nail hammer, No. 3.
- 1 set Jennings' bitts.
- 1 set framing chisels.
- 1 axe and handle.
- $\frac{1}{2}$ doz. each axe and hammer handles.
- $\frac{1}{4}$ doz. each $4\frac{1}{2}$-in. taper, 12-in. $\frac{1}{2}$ round bast. files.
- $\frac{1}{4}$ doz. 12-in. flat bast. files.
- 10 lb. assd. $\frac{1}{2}$ to $\frac{3}{4}$-in. wrought washers.
- 150 ft. 1-in. diam. rope.
- 1 12-in. Coe's black wench.
- 1 each twist drill $\frac{1}{4}$, $\frac{6}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$-in.
- 5 steel sledges, two 7-lb., two 8-lb., one 10-lb.
- 1 steel square.
- 1 each iron stoping bars, $\frac{3}{4}$, 1, $1\frac{1}{2}$-in. by 6 ft.
- 100 lb. assd. machine bolts, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$-in.
- 2 No. 10 scoop shovels.
- 1 14-in. steel rake.
- 1 each stone hammers 8 and 10 lb.
- 1 No. 3 claw hatchet.
- 1 rachet brace.
- 1 each fore and jack plane.
- 1 No. 2 machinist B. P. hammer.
- 1 doz. sledge handles.
- 2 charcoal forks, short handle.
- 1 60-lb. grindstone.
- 1 set grindstone fixtures.
- 1 each single and double pat. blocks.
- 2 lb. copper rivets and burrs, $\frac{7}{8}$-in. No. 5.
- 1 ratchet drill stock.
- 1 N. Y. B. stock and dies.
- 1 spirit level.
- 12 bars oct. steel—

  4 2 3 3

  6 each ends $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$-in.

BLACKSMITH'S OUTFIT.

- 1 No. 1 riveting hammer.
- 1 No. 3 blk. striking hammer.
- 2 solid steel sledges.
- 1 swage block.
- 4 P. W. anvil.
- 1 G. H. tuyere.
- 1 set top and bottom swages, $\frac{3}{8}$ to $1\frac{1}{2}$.
- 2 square flatters.
- 2 round flatters.
- set hammer.
- 2 hot cutters.
- 2 cold cutters.
- 2 rd. punches, $\frac{3}{8}$ by $\frac{1}{2}$.
- 2 gouge chisels.
- 1 $\frac{1}{2}$ round heading tool.
- 1 $\frac{1}{2}$ square heading tool.
- 2 Hardies.
- 6 pair assorted tongs.
- 1 P.W. vice.
- 1 36-in. extra long bellows.

Approximate cost, 90 dols.

PIPE FITTINGS.

1 each pipe stock and dies, Nos. 1 and 2.
1 pair each Brown's tongs, Nos. 2 and 4.
each unions $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and two 2-in.
6 each tees $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and two 2-in.
6 each nipples, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and two 2-in.
2 1-in. hose bibs, S. S. & S.
1 each pipe cutters, Nos. 1 and 2.
2 each extra cutters, Nos. 1 and 2.
6 couplings, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and four 2-in.
6 ells, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and two 2-in.
1 comb. pipe vice.

Approximate cost, 100 dols.

RUBBER GOODS.

50 ft. 1-in. by 4 ply hose in 2 pieces.
1 yd. $\frac{1}{4}$-in sheet packing.
2 coils each $\frac{3}{8}$, $\frac{1}{2}$-in. tucks square packing.
10 lb. hemp packing.
1 1-in. nozzle and couplings.
2 yd. each $\frac{1}{8}$, $\frac{1}{16}$-in. sheet packing
1 side lace leather.

Approximate cost, 60 dols.

MISCELLANEOUS.

2 soldering irons.
3 bars solder.
6 spring oilers.
1 keg dry red lead.
5 10 by 14 square lanterns, with reflectors.
6 tubular lanterns.
3 tubular lantern globes, extra.
12 lantern glasses.
12 lantern chimneys.
4 doz. wicks.
1 6-in. round clock.
4 bbls. fire clay.
4 bbls. fire sand.
2 1000-lb. D. L. platform scales, Howe's broad wheel.
1 1-gal. oil can.
1 lamp filler can.
1 keg white lead, in oil.
1 14-in. tin head-light.
1 $\frac{1}{4}$-in. mesh sand screen, with frame.
2 each sheet iron, Nos. 10 and 16.
1 No. 2 warehouse truck.
100 square fire brick.
50 key fire brick.
200 wedge fire brick.
20 gal. valvoline, in $\frac{2}{5}$-cases, for engine cylinder.
40 gal. extra W. S. lard oil, in $\frac{2}{5}$-cases.
$\frac{1}{2}$ doz. zinc oilers.
1 long spout oiler.

Approximate cost, 340 dols.

ORES, TREATMENT OF.

The following synopsis embraces the recognised methods of dealing with various ores, two or more methods being sometimes adopted in combination.

If free *gold* can be panned out and no sulphurets = Free gold milling.

Free *gold* found, but also sulphurets, which on being panned out, after free gold is separated, assay sufficiently well to pay for treatment after = Free gold milling, with vanning machines for tailings; chlorination, or smelting for product.

Free *gold* in small quantities, but much *silver* present in sulphurets = Roasting milling; or free gold milling, vanners, and smelting; or copper plates, vanners, and pans.

Chloride of *silver* ores, and decomposed silver vein outcrops, over 6 oz. per ton = Free silver milling.

Silver ores consisting of part chloride or decomposed, and part silver-bearing sulphurets = Free silver milling, vanners and smelting; or if grade of ore is high = Roasting milling.

Silver ore with base metal sulphurets, if low grade = Fine concentration and smelting; if higher grade = Roasting milling.

Low grade *silver* ores, with gray *copper*, *tellurides*, ruby, brittle, or native silver = Fine concentration and smelting.

Heavily mineralised ores of *lead*, *copper*, *zinc*, often carrying *silver* = Coarse concentration and smelting.

Lightly mineralised ores of *lead*, *tin*, *copper*, *zinc* = Fine concentration and smelting.

Carbonate or oxide of *lead* or *copper* = Smelting.

Solid *galena* ores = Smelting, either after simple hand selection, or hand selection and coarse concentration on rejected ore.

Metallic *copper* ores = Stamping, with coarse concentration, and melting to ingot.

Antimony ores = Hand-picking, coarse or fine concentration, and smelting for metal.

Zinc-blende and *zinc*-carbonates = Coarse or fine concentration, and reduction by a zinc smelting process.

Tin ores = Fine concentration, roasting, and smelting.

Copper pyrites and copper glance = Hand-picking, coarse or fine concentration, partial roasting and matting; or if on seaboard, shipment of selected and concentrated product to refineries; or if low grade, sometimes lixiviation for copper and silver.

Heavy *iron* pyrites, carrying *gold* = Chlorination process; or roasting and intermixture with smelting ores.

COAL CLEANING.

Table 122.—COAL CLEANING: *Cost.*

Makers.	Where in Operation.	Pence per Ton.
Bell, Wishaw	Tannochside	4·6
M'Culloch	Devon	4·48
Carlton Iron Co.	East Howle	1·24
Bell & Ramsay	Tursdale	1·27
Bolchow, Vaughan, & Co.	Binchester	1·48
Coppée	Dowlais Co.	5·3
Sheppard	Kinneil Iron Co.	2·5
Carron Co.	Carron	7·6

Table 123.—COAL CLEANING: *Results and Cost.*

Name of Washer.	Total Cost.	Quantity of Water used per Ton.	Loss per Ton in Dross left in Rubbish, calculated at 2*s.* per Ton.	Cost of Washing per Ton.	Cost per Ton of Dross to Redeem Capital at 10 per cent., 30,000 Tons per annum.	Total Cost of Washing per Ton.
	£	gal.	*d.*	*d.*	*d.*	*d.*
Bash Machine—			*	*	*	
Bell & Sons, at Tannochside	500	200	1·7	2¼	·4	2·9
M'Culloch's, at Devon ..	600	200	say 1·0	3	·48	3·48
Trough—						
East Howle	300	350 to	nil	1	·24	1·24
Tursdale	250	400	·7	1	·20	1·20
Rotary—						
Robinson	250	30	·2	1	·20	1·20
Felspar—						
Coppée	2500	300	·3	3	2·00	5·30
Sheppard	500	..	·1	2	·4	2·40
Carron—						
Experimental	..	..	·4	7	..	7·40

* Labour, cost, and depreciation only included, power and other establishment charges not included.

Table 124.—COAL CLEANING: *Results.*

Name of Colliery.	Name of Washing Machine.	Rubbish in Dross Coal previous to Washing.	Rubbish left in Washed Dross Coal.	Quantity Rubbish removed by Washing Operation.	Coal in Rubbish removed by Washing.	Total Rubbish and Coal taken out in Operation of Washing.	Percentage of Total Rubbish in Dross taken out in Washing.	Weight of Dross lost as being mixed with Rubbish taken out in Operation of Washing on every 100 Tons Washed.	Weight of Rubbish left in every 100 Tons of Washed Dross.
		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	tons cwt. qr.	tons cwt. qr.
Dowlais ..	Coppée	22·64	3·24	19·40	5·70	25·10	85·69	1 8 2	0 16 0
East Howle	Ramsay trough	25·35	13·51	11·84	trace	11·84	46·80	trace	1 11 3
Binchester	Robinson	27·23	18·24	8·99	3·80	12·79	33·00	0 9 2	2 6 2
Tursdale ..	Bell & Ramsay trough ..	13·84	3·40	10·44	13·38	23·82	75·44	3 3 2	0 16 0
Kinneil ..	Sheppard	15·37	9·06	6·31	4·25	10·56	39·90	0 8 3	0 19 0
Devon ..	M'Culloch	39·26	..	..	38·13	..	..	..	..
Carron ..	Trough	14·32	4·45	9·87	9·14	19·01	68·92	1 14 2	0 16 3
Woodend ..	.. ..	20·00	11·00	9·00	23·00	32·00	45·00	7 6 0	..

Table 125.—COAL CLEANING: *Statements Contrasting Practice at several Collieries.*

I. *Dry Cleaning.*

Name.	Speed per Minute of Picking Bands.	Number of Belts.	Total Length of Bands.	Total Length of Band available for Operating on.	Capacity.	Vibration of Screens per Minute.	Inclination.
	ft.		ft.	ft.			
Barrow	30 to 35	..	..	..	1200 to 1500 tons daily	80 to 100	1 in 2·4
Aldwarke Main	40 „ 50	3	180	180	600 tons in 8 hours ..	106	1 „ 3
Nunnery Main	60	3	120	120	.. ..	..	1 „ 4
„ Nut ..	40	1	62	60	.. ..	..	1 „ 4
Annesley	30 to 35	1	250	250	700 tons in 8¼ hours ..	115	1 „ 4
Clifton	15	2	60	10	350 to 400 tons per day of 10 hours	All fixed	1 „ 1·8

II. *Wet Cleaning.*

Name.	Type of Machine.	Nominal Capacity per Day of 10 Hours.	Actual Capacity per Day of 10 Hours.	Dirt in Coal.	Taken out.	Left in.	Smudge Tanks. Capacity.	Settling Ponds. Capacity.	Tank Capacity per Ton washed per Hour.	
									Smudge.*	Settling.*
		tons	tons	per cent.	per cent.	per cent.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
Barrow ..	Robinson	300	240 to 280	..	8 to 10	4	6,500	21,640	2·17	7·76
Aldwarke ..	Trough ..	..	180	..	12	4	20,115	Nil	11·27	Nil
Nunnery ..	„ ..	..	220	..	10	..	5,000	16,000	..	..
Clifton ..	Coppée ..	400	300	..	15 to 18	..	12,150	..	3·04	..

* These are calculated on maximum capacity of the apparatus for want of more reliable data.

Table 125—*continued.*—III. *Trough Washing.*

Name.	Dimension of Double Trough Washer.	Washing Capacity.	Inclination of Troughs.	Dirt Removed.	Dirt Left in.	Remarks.
				per cent.	per cent.	
Aldwarke Main ..	50 yd. 16 by 9	150 tons in 12 hours..	$1\frac{1}{2}$ in. per yd.; washer same inclination ..	12	4	Crushed.
Nunnery	36 yd. 16 by 9	220 tons in 10 hours..	From coal hopper to troughs 2 in. per yd.; washer level	10	..	Smudge and peas not crushed.

Name.	Box. Length.	Box. Breadth.	Box. Depth.	Weight.	Capacity.	Diameter of Wheels.	Gauge.	Wheels.	Doors.	Ends.
	ft. in.	ft. in.	ft. in.		cwt.	in.	in.			
Barrow	4 0	3 0	2 0	..	9 to 10	8	24	Flange	None	Fast
Aldwarke	3 6	2 10	2 0	$3\frac{3}{4}$	8 to 9	8	..	,,	,,	,,
Nunnery	4 0	3 0	2 0	..	9 to 10	$10\frac{1}{2}$	28	,,	,,	,,
Annesley	4 0	3 0	2 0	..	11	..	26	,,	,,	Open
Clifton	3 6	3 0	1 8	..	7	8	22	,,	,,	Fast

NOTE.—All are made of wood.

Table 125—*continued.*

V. *Costs (Labour and Repairs only) per ton of Coal.*

Name.	Dry Cleaning.	Wet Cleaning.	Type of Washer.	Condition of Coal previous to Washing.
	d.	*d.*		
Barrow	1¼	2¼	Robinson	Crushed.
Aldwarke Main	..	2¾	Trough	"
Nunnery	3	1·40	"	Not crushed.
Annesley	2¼ to 3	No cleaning here.	..	..
Clifton	3 to 4	6 to 7	Coppée	Not crushed.*

* Machine not in complete effective working.

COAL CLEANING: *Generalities.* (Min. Inst. Scotland.)

The methods and appliances in use in any one district can seldom be adopted as a whole in a similar form in another. This applies in many instances to collieries in the same district, and even to different seams worked by the same shaft. The nature of the coal, the associated and interbedded strata, the skill, customs, and prejudices of workmen, the markets to be supplied, the varying requirements of competition, and the caprice of the public, have all to be taken into account when designing plant for classifying and cleaning coal.

While coal with marked characteristics can with care be selected underground so as to be filled separately, no process can be profitably applied underground for effectually removing refuse, especially the smaller particles. To clean coal properly, it must be treated on the surface.

As a considerable percentage of dross is made in transit from the cage to the railway wagon, it is evident that the best results are got where attention is paid to the form of hutch and tumbler, the inclination of screens, and the drop into wagons; and this is specially important in the case of soft coals. A number of contrivances to lessen breakage are mentioned in the report. The careful hand-packing of large coal into the wagons, as practised in the Nottingham district, has advantages.

For effective screening, especially when a large output has to be dealt with, there appears to be no better contrivance than the single or double jigger, or shaking screen, going at 90–100 strokes per minute, and having an inclination suited to the class of coal to be dealt with. There is a preference for wire-meshing for such screens at some collieries, and at others bars or perforated plates are preferred.

For picking, the shaking screen just referred to, or the travelling band, or both combined, is the most effective and economical—the

Generalities—continued.
band being about 4 ft. wide, 40–60 ft. long, and moving at a speed of 30–60 ft. per minute, according to the quantity of coal to be passed. Ample length of band allows large coal to be sized and loaded into separate wagons by hand with despatch and economy.

In every case it is necessary that the coal be delivered regularly from the tip hopper to the jigger or travelling band. This can be accomplished by regulating sluices worked by an attendant or automatically by the intervention of a slow-motion band.

Good light is essential to efficient picking.

A rough rule for deciding the number and length of picking tables may be stated as follows:—One picking table for every 30 tons per hour of triping output, travelling at the rate of 40 ft. per minute, and having a length of 10 ft. for every 3 per cent. of material to be picked off, plus 15 ft.

The cost for labour of this system may be taken at about $1\frac{1}{2}d.$–$2d.$ per ton of round coal for every 5 per cent. of material picked out of that coal.

For round coal, say above $1\frac{1}{2}$ in. cube, the dry process is universally employed, and this process can be successfully applied to nuts from say $\frac{3}{4}$ in. upwards, where the refuse does not exceed 2–3, or even 4 per cent.; and the table capacity required, judging from the examples in the report, is about one table for every 20 tons per hour, travelling at the rate of 30 ft. per minute, and having an effective length of 15 ft. for every $1\frac{1}{2}$ per cent. of material picked off. The cost for labour will probably be $\frac{3}{4}d.$–$1\frac{1}{4}d.$ for every 1 per cent. picked off. Balanced screens, on which the coal is picked, are available only when the amount of material to be picked off is very small, say 1–$1\frac{1}{2}$ per cent. For all small under $\frac{3}{4}$ in., and for dross from $1\frac{1}{2}$ in. downwards, with more refuse than 2–4 per cent., the wet process is most applicable.

In the wet process it is desirable to have the arrangement so that the small coal can be delivered direct from the screens into the washing tanks without the intervention of wagons. In all the systems of washing, the best results are obtained by sizing the small coal before it reaches the machine. This can most conveniently be done by passing it through revolving screens with meshes of varying size. The supply and degree of pulsation or agitation of the water require careful adjustment to suit the various sizes of coal to be treated, and the relative specific gravity of coal and impurities.

To remove the refuse from the smaller sizes, say under $\frac{3}{8}$ in., the felspar washer is the most effective. The felspar system is the most valuable where the coal is crushed before washing and is to be used for coke making.

Where the coal and the refuse approach one another in specific gravity, it appears that in some cases the trough washer gives the best results. It is applicable for small quantities only, and requires a large flow of water and extra labour, but it has the recommenda-

Generalities—continued.

tion of simplicity and small capital cost. It may also be sometimes utilised as a means of transport where the distance from the pit to the wagons or coke ovens is considerable.

The Robinson washer is cheap as regards first cost and upkeep, and requires little water. It largely depends for its efficiency on the attention and skill of the man in charge, who may often be tempted to pass more through it than it can effectually clean.

Speaking generally, more elaborate machinery is effective in avoiding waste in proportion to its cost; but the capital charges and upkeep are also high in proportion.

Other things being equal, coal will be washed best with an abundant supply of clean water; but the more water used, the greater the risk of fine coal being lost, and the greater the difficulty of filtration. Water to wash coal for coking should not be often used over again, as dirty water dulls the coke.

The particulars furnished as to settling ponds do not give sufficient data to justify any definite conclusion as to their capacity in relation to the quantity of coal washed. In most cases no record was kept of the quantity of water used; but settling ponds are a necessity, and their capacity will depend on the special circumstances of each case.

There seems no better way of filtering the foul water, after it has passed through the settling ponds, than pumping it on to the rubbish heap, and allowing it to percolate through, as at Earnock.

The washed gum of coal not suited for coking is meantime used almost entirely for firing colliery boilers. Briquettes are made of it to a small extent, but new outlets are required for this product.

The large quantity to be treated daily, and the varying nature and proportions of the coal and dirt to be separated, render washing, at most collieries, a troublesome process; and unqualified satisfaction is seldom expressed as regards any machine in use. In some cases the machine may not be quite adapted to the peculiarities of the coal treated, or it may be over-driven, or not have a sufficiency of water, or be allowed to get out of repair, all or any of these causes leading to disappointment as to results.

A separate siding for each class of coal is a desirable arrangement.

MINE SURVEYING.

MEASURING INACCESSIBLE DISTANCES.

1. In measuring along the line *a b*, Fig. 12, a river intervenes, so that the distance *c b* is inaccessible to direct measurement with a chain. From the point *c* set off a line *c d* at right angles to the line *a b*, and erect a staff at the point *d*. Then set off a line *d e* at right angles to the imaginary line *d b*, till it cuts the line *a c*. Measure the line *c e*. Then as *c e* is to *c d*, so is *c d* to *b c*. Say *c e* = 60 ft., and *c d* = 90 ft.; then 60 : 90 :: 90 : 135; thus *b c* = 135 ft.

2. To apply the theodolite to the foregoing example, plant the theodolite at *a*, Fig. 13, and at any convenient distance raise a perpendicular *a b*; then remove the theodolite to *b*, and make the angle *a b c* = the angle *a b d*. The distance between *a c* will = the distance between *a d*.

3. Or, set up the theodolite at *a*, Fig. 14, and measure any angle, say 90°; walk along the line *a b* till the theodolite reads half the angle (45°); measure the distance *a b*, which will = the distance *a c*.

4. Or, plant the theodolite at *c*, Fig. 15, and prolong the line *a c* to *d*, and the line *b c* to *e*; measure the lines *a c* and *b c*, making *a c* = *c d* and *b c* = *c e*. The distance *d e* will then = the distance *a b*.

5. On the line *a b*, Fig. 16, an inclosed plantation intervenes. Then at points *c* on line *a b* plant staves, and from each point set off at right angles to the line *a b* lines *d*, and at right angles to these lines *d* set off a new line *h i*, which will pass the obstacle, repeating these operations with lines *f g* in order to regain the original line *a b*.

6. On the line *a b*, Fig. 17, a building interrupts the surveyor. To overcome this by means of a chain and angular instrument, the first step is to measure an angle which will clear the obstacle, viz. *a c d*, at say 140°. At the point *d* the theodolite is then planted, and a second angle *d e b* is measured off = the supplement of the first, or 70°. Measure along the line *d e* till a point is reached exactly = the length of the line *c d*. Place the transit at *e*, and with the telescope pointing on *d*, get the angle exactly 140° or = the angle *a c d*. Then the true continuation of the line *a b* is found by bringing a staff into the line marked by the cross-hairs of the telescope.

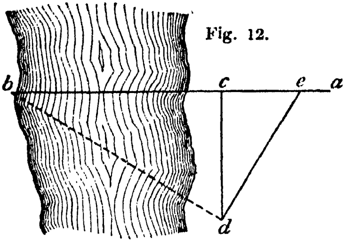


Fig. 12.

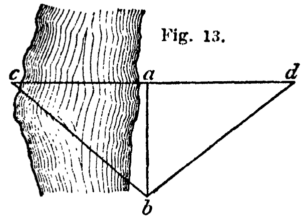


Fig. 13.

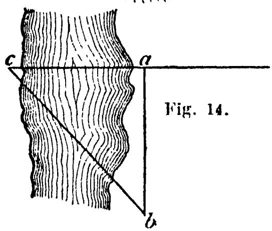


Fig. 14.

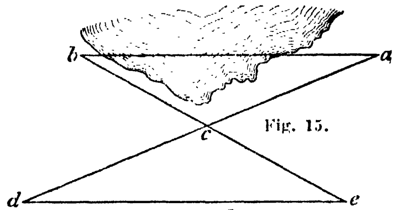


Fig. 15.

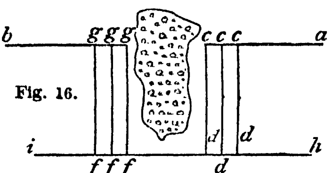


Fig. 16.

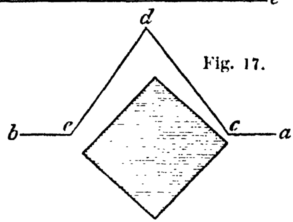


Fig. 17.

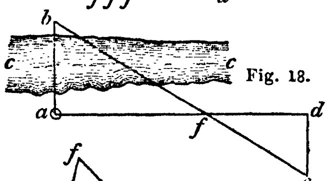


Fig. 18.

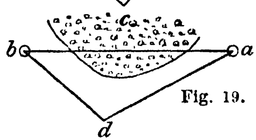


Fig. 19.

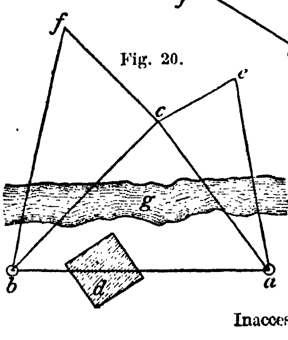


Fig. 20.

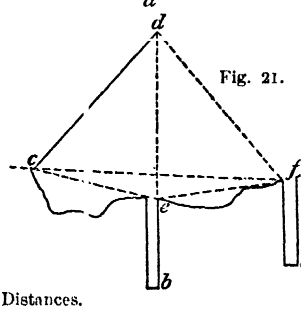


Fig. 21.

Inaccessible Distances.

MEASURING SHAFTS, LEVELS, AND INCLINES.

Shafts.—To find Distances between.

1. To find the distance between two shafts *a b*, Fig. 18, separated by a stream *c*, plant a staff at *b* in line with *a*, and set off a line *a d* at right angles to the line *a b*, fixing a staff at *d*. Then at right angles to the line *a d* draw a line *d e*, fixing a staff at *e*. Next, from the point *a*, measure off a certain distance on the line *a d*, and fix a staff at the spot, say *f*; adjust the staff on the line *d e*, so that it exactly covers the staff *b f*. Measure the intervals between *a* and *f*, *f* and *d*, *d* and *e*; then as the angle *a f b* = the angle *d f e*, and *a* and *d* are each right angles, therefore as *f d* is to *d e*, so is *a f* to *a b*;

or, *f d* (say 100 ft.): *d e* (70 ft.) :: *a f* (200 ft.): *a b* (140 ft.).

2. To find the distance between two shafts *a b*, Fig. 19, when a plantation *c* intervenes, set up the theodolite at *d*, and take the angle *b d a*, say = 90° 30′; measure the distances between *d* and *b* and *d* and *a*, say respectively 48 and 62 chains. Then draw the line *d b*, and at *d* mark off the angle with the protractor = 90° 30′. By applying the scale to *d b* mark off 48 chains, and by the same process to *d a* 62 chains; then, on joining the points *a b* and applying the same scale, the distance will be arrived at.

3. To find the distance between two shafts *a b*, Fig. 20, which are simultaneously visible only from one spot *c* on the opposite side of a stream, and are separated by a building *d*, plant the theodolite at *c*, and fix poles at known intervals at *e* and *f*. Measure the angles *a c b*, *a c e*, and *a e c*. The distance between *c* and *e* being known, the length of the line *a c* can be ascertained by the rule "given one side and two angles of an oblique-angled triangle, to construct it and measure the other parts." Next measure the angles *b c f* and *c f b*, and thus find the length of the line *c b*. Then having found the lengths of the lines *a c*, *b c*, and the angle *a c b*, the length of *a b* may be deduced as in *Ex.* 2.

4. To find the distance between two shafts, and of each shaft from two distant stations, the distance between the stations and the horizontal angles with the two shafts from the stations being known. Thus in the case of the two shafts *a b*, Fig. 21, given the horizontal angles by transit theodolite to be:—*e c d* = 106° 48′ 20″, *f c d* = 90° 35′ 15″, *c d e* = 23° 40′ 15″, *c d f* = 57° 17′ 30″, and the line *c d* = 890 links; then make a horizontal line *c d* exactly 890 links long; with the protractor set off from *c d* with its centre at *c*, the angle *e c d* at 106° 48′ 20″, and from the same centre the angle *f c d* at 90° 35′ 15″. Then draw the lines *c e* and *c f* to any convenient length. Next, setting the protractor to the line *c d* with its centre at *d*, set off the angle *c d e* at 23° 40′ 15″, and *c d f* at 57° 17′ 30″, and remove the instrument. Then, having drawn the lines *d e* and *d f*, the point of intersection of *d e* with *c e* will give the position of the first shaft; the intersection of *d f* with *c f* will give the position of the second shaft; application of the scale to

Shafts—continued.
the line $e\,f$ will give the distance from shaft a to shaft b; and lines $d\,e$ and $d\,f$ measured on the same scale will give the distances of the stations $c\,d$ from each shaft.

Shafts.—To find Depths for.

1. To find the depth at which the shaft $a\,b$ Fig. 22 will strike the vein c, when the underlie of the vein and the distance between the outcropping d and the top a of shaft are known, assume the angle $b\,d\,a = 44°\,40'$ and the distance a to $d = 90$ links; draw a horizontal line $a\,d$, set off the line $d\,b$ at $44°\,40'$, and measure 90 links on $a\,d$; a perpendicular line falling from a will strike the vein c at b, and the length from a to b will be the depth of the shaft in links.

2. Or, multiply the natural tangent of the angle $b\,d\,a$ by the distance a to d, thus—

Natural tangent of angle $b\,d\,a$ $44°\,40'$	=	·988432
Distance a to d	=	90
Depth of shaft in links	=	88·958880

3. To find the depth required in a second shaft to reach the same bottom level as the first shaft, when the depth of the first shaft and angle of elevation and hypothenuse of the second shaft are known. In Fig. 23, the depth of the first shaft $a\,b = 87$ yd., the angle of elevation $c\,a\,d = 32°\,25'\,30''$, and the hypothenuse $a\,d = 220$ yd. Then draw the horizontal line $e\,f$, and from it measure up 87 yd. from b to a; with the protractor applied to the line $e\,f$, centre at f, set off the angle $c\,b\,c$ at $32°\,25'\,30''$; with a parallel rule draw the line $a\,d$ parallel to $b\,c$, so that the angle $c\,a\,d$ will = the angle $c\,b\,c$. Then a perpendicular line dropped from a point d on the line $a\,d$ at 220 yd. from a, will give the depth in yd. which the new shaft $g\,h$ sunk at d must have in order to reach the same level as the bottom of shaft $a\,b$.

4. Or, multiply the sine of the angle of elevation by the hypothenuse for the perpendicular, and the cosine of the angle of elevation for the base. Thus in Fig. 24, the shaft $a\,b$ is 80 yd. deep, the angles of elevation (in this instance being two, owing to the inequality of the surface) are $39°\,31'$ at a, and $15°\,11'$ at c, while the hypothenuse $a\,e = 240$ yd., and $c\,d = 160$ yd. Then—

Angle a $39°\,31'$ = sine $·636303 \times 240$ =	152·712720
Angle c $15°\,11'$ = sine $·261909 \times 160$ =	41·905440
Total difference of level $d\,e$ =	194·61816
Add depth of shaft $a\,b$ =	80
Total depth of shaft $d\,f$ =	274·61816

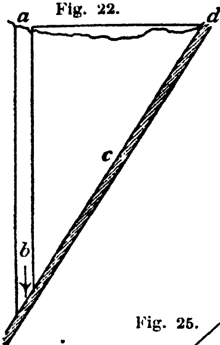


Fig. 22.

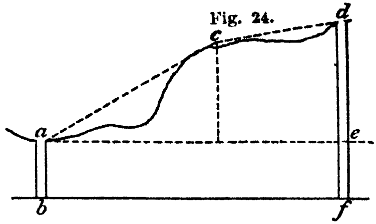


Fig. 24.

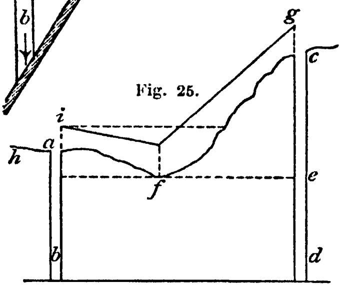


Fig. 25.

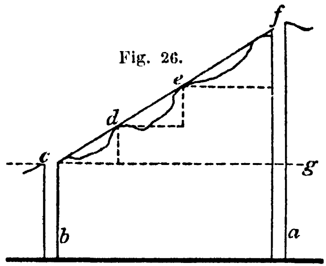


Fig. 26.

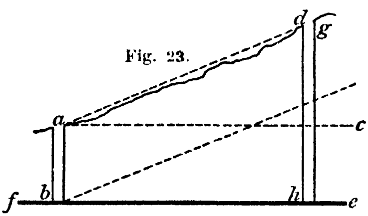


Fig. 23.

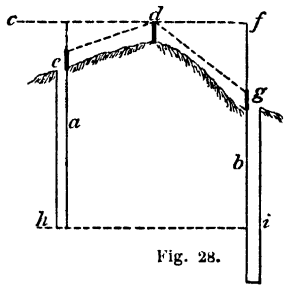


Fig. 28.

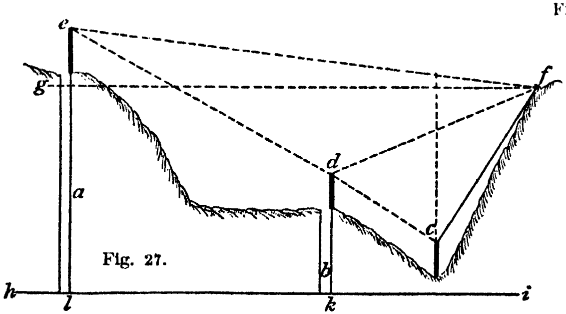


Fig. 27.

Shafts.

Shafts—continued.

Shafts.—To find differences of Level of.

1. At top. The angles of elevation between the two shafts *a b* and *c d*, Fig. 25, and the hypothenuse being known, their difference of level at the mouth is found in the following way. Suppose the angle of elevation *e f g* = 44° 20′, and the angle *h f i* = 10° 35′, while the hypothenuse *g f* = 870 yd., and the hypothenuse *i f* = 630 yd. Then draw the horizontal line *h e*, set off the above angles from *f*, and mark the distances named on *g f* and *i f*. The difference of level between the intersection of the telescope of the theodolite at *i*, and a staff of similar height at *g* will give the difference of elevation between the mouths of *a b* and *c d*; or it may be seen from the scale.

2. Or, supposing the angles of elevation in Fig. 26, between shafts *a* and *b* on the line *c g*, to be from *c* = 42° 10′, from *d* = 41° 40′, from *e* = 43° 25′, and hypothenuse *c d* = 80 yd., *d e* = 85 yd., *e f* = 120 yd., then multiply the sines of the angles by the hypothenuses, thus—

Angle from	*c* 42° 10′ = sine ·671290	×	80 =	53·7032
„	*d* 41° 40′ = sine ·664796	×	85 =	56·50766
„	*e* 43° 25′ = sine ·687299	×	120 =	82·47588
	Total difference of level in yd. =			192·68674

3. Or, when the angles of elevation or depression from two distant stations are known. Suppose two shafts *a b*, Fig. 27, and that the angle from station *c* to point *d* = 45° 10′, that from *c* to *e* = 44°, and that from *c* to *f* = 60°, and the line *c f* = 1000 links. Take at *f* the angle of depression *f* to *d*, or *g f d* = 30° 15′ 22″, and the angle of elevation *f* to *e*, or *g f e* = 15° 9′ 11″. Draw the horizontal line *h i*, and from point *c* set off angle *h c d* = 45° 10′, angle *h c e* = 44°, and angle *i c f* = 60°. From point *c* draw the lines *c d*, *c e*, *c f*, making the length of *c f* = 1000 links, and *f g* parallel to *h i*. At point *f*, set off the angles *g f d* = 30° 15′ 22″, and *g f e* = 15° 9′ 11″, and draw the lines *f d*, *f e*. Then the point where *f d* intersects *c d* will be the top of shaft *b*, and the point where *f e* intersects *c e* will be the top of shaft *a*. Applying the same scale as before to the lines *d k* and *e l*, their difference will = the difference in elevation of the mouths of the two shafts.

4. At bottom. Suppose the depth of shaft *a*, Fig. 28, = 60 yd., and of shaft *b* = 55 yd., while the angle of depression *f d g* = 43° 10′ 15″, angle *c d e* = 21° 2′ 10″, the distance *g d* = 500 yd., and the distance *e d* = 400 yd. Then draw the horizontal line *c d f*, and with the protractor set off from *d* the angle *f d g* at 43° 10′ 15″, and the angle *c d e* at 21° 2′ 10″, and draw the line *g d* = 500 yd., and the line *e d* = 400 yd. The points *e g* are thus the tops of the shafts *a b*, and perpendicular lines

Shafts—continued.
dropped from the horizontal line $c\ d\ f$ to the points $e\ g$ will give, when measured on the scale, the differences in elevation at the mouths of the shafts. Then prolong these perpendicular lines and measure on a 60 yd., and on b 55 yd. in depth, and draw the horizontal line $h\ i$ from the bottom of shaft a, so that it intersects shaft b. The difference between the horizontal line $h\ i$ and the bottom of shaft i on the scale is the measure sought.

Levels.—To find Length required.

1. When the depth of the shaft, its distance from the vein, and the dip of the vein are known.

Suppose the shaft a, Fig. 29, is 50 yd. deep and 100 links distant from the outcrop b of the vein c which dips at 40°. Connect the outcrop b with the top of shaft a by drawing the line d = 100 links, and from the line $b\ d$ at b, set off the angle $g\ b\ d$ = 40°. A perpendicular line from d, 50 yd. deep, will represent the shaft. From the bottom of the shaft draw the horizontal line $e\ f$ parallel to $d\ b$ and measure it by the scale; the number at the point of intersection between $e\ f$ and $b\ g$ = length of level in links.

2. Or suppose the depth $c\ d$ of the shaft a, Fig. 30, = 50 yd., and the angle $c\ d\ e$ = 44° 10′, being the dip of the vein b, then the

Natural tangent of $c\ d\ e$ 44° 10′	=	·971326
Multiplied by the depth $c\ d$	=	50
Length of level $c\ f$ in yd.	=	48·566300

3. Or, suppose the depth of shaft a, Fig. 31, = 50 yd., the distance $d\ e$ between the shaft a and outcrop of vein b = 120 yd., and the angle $d\ e\ f$ or dip of vein = 40°, then the

Natural tangent of angle $d\ e\ f$ 40°	=	·839100
Multiplied by distance $d\ e$	=	120
Distance $d\ f$	=	100·692000
Less distance $d\ g$	=	50
Then distance $g\ f$, in yd.	=	50·692000

The angle at f = 90° − angle at e (which is, say 47° 10′), or f = 42° 50′, then the

Natural tangent of e 42° 50′	=	·927091
Multiplied by distance $g\ f$	=	50·5
Length of level c, in yd.	=	46·8280955

Levels.—To find Depth at which known Length shall strike the Vein.

1. Suppose the depth of shaft *a*, Fig. 29, = 50 yd., the distance from shaft *a* to outcrop *b* of vein *c* = 100 links, the dip of vein *c* = 40°, and the length of level *e f* = 20 yd. Draw the horizontal line *d b* 100 links long, and at *b* set off the angle 40°; drop a perpendicular line *d e*, and apply a parallel ruler to the line *d b*, running it down till the level *e f* exactly fills the space between *d e* and *b g*. This spot will indicate where the level will touch the shaft *d e*, and the depth may be ascertained by applying the scale to the shaft *d e*.

2. When the shaft is continued below the vein and a returned heading is made. Suppose the shaft *a*, Fig. 32, to be distant 120 yd. from the outcrop *e* of the vein *b*, the angle of dip of vein *b* to be 47° 12′, and that the shaft *a* is continued in depth for 80 yd. below the point where it intersects the vein *b*. Draw a horizontal line *d e*, and from the point *e* set off with the protractor the angle 47° 12′; then a perpendicular line *d f* falling from *d* will intersect the vein *e g* at *h* (and by measuring on the scale will give the depth of shaft *d f* to that point), and extended 80 yd. deeper to *f* will indicate where the level is to be run; apply the parallel ruler to *d e*, run it down to point *f*, and apply the scale to line *g f*.

Levels.—To find Depth of Shaft at Intersection of Vein, and Lengths of Levels, when one level is above and one below the intersection.

Let the distance *d e*, Fig. 32, = 120 yd., the angle of dip = 47° 12′, the depth of shaft *a* from *d* to first level *i k* = 30 yd., and the depth from *h* to *f* = 80 yd.; then the

Natural tangent of angle at *e* 47° 12′	=	1·079902
Multiplied by distance *d e*	=	120
		21598040
		1079902
Depth at intersection, in yd.	=	129·588240
Less depth *d i*	=	30
Depth *i h*, in yd.	=	99·588240

The angle at *h* = 90° − 47° 12′ = 42° 48′; then the

Natural tangent of angle at *h* 42° 48′	=	·926010
Multiplied by distance *i h*	=	99·5
Length of level *i k*, in yd.	=	92·1379950

Also the

Natural tangent of angle at *h* 42° 48′	=	·926010
Multiplied by distance *h f*	=	80
Length of level *g f*, in yd.	=	74·080800

Levels.—To find Direction and Length when required to strike a fixed point at right angles.

Thus, in Fig. 33, it is required from the bottom of incline a to drive a level b so as to cut the shaft c at right angles. Suppose incline a to be 60 yd. long and shaft c to be 30 yd. deep, then divide the side c opposite the required angle of b by the hypothenuse, and the quotient will be the sine of the angle. Thus,

60) 300 (·5 = sine 30°
300

The angle at $d = 90° - 30° = 60°$. Then the

Natural cosine of angle at e 30°	=	·866025
Multiplied by a	=	60
Length of level b, in yd.	=	51·961500

Or, the

Natural tangent d 60°	=	1·732051
Multiplied by c	=	30
Length of level b, in yd.	=	51·961530

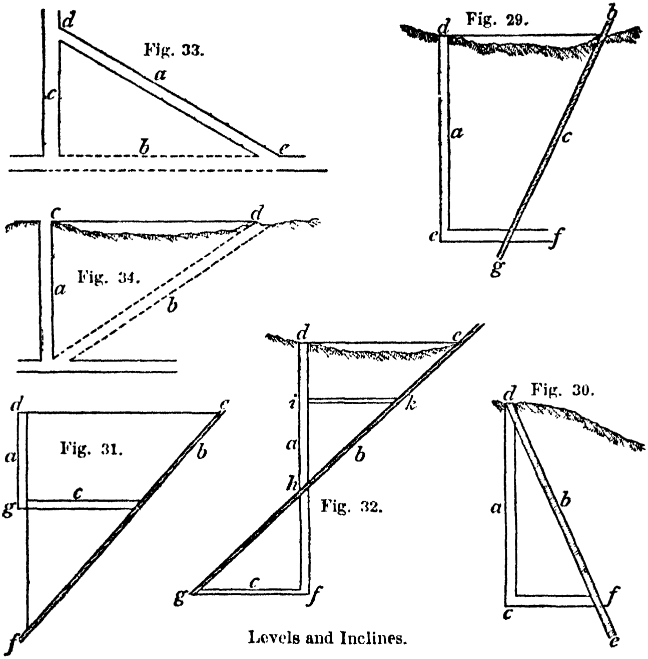
Inclines.—To find Direction and Length.

In Fig. 34, suppose the depth of shaft $a = 80$ yd., the distance $c\,d = 60$ yd., then find the length and angle of incline b so as to strike the surface at d. Divide the side a opposite the required angle by the other side $c\,d$; the quotient will be the natural tangent of the angle. Thus:—

80) 6000 (·75 = tangent 36° 52′
560

The angle at $d = 90° - 36'' \; 52' = 53° \; 8'$. Then the

Natural secant of 53° 8′	=	1·666792
Multiplied by $c\,d$	=	60
Length of incline b, in yd.	=	100·007520



Levels and Inclines.

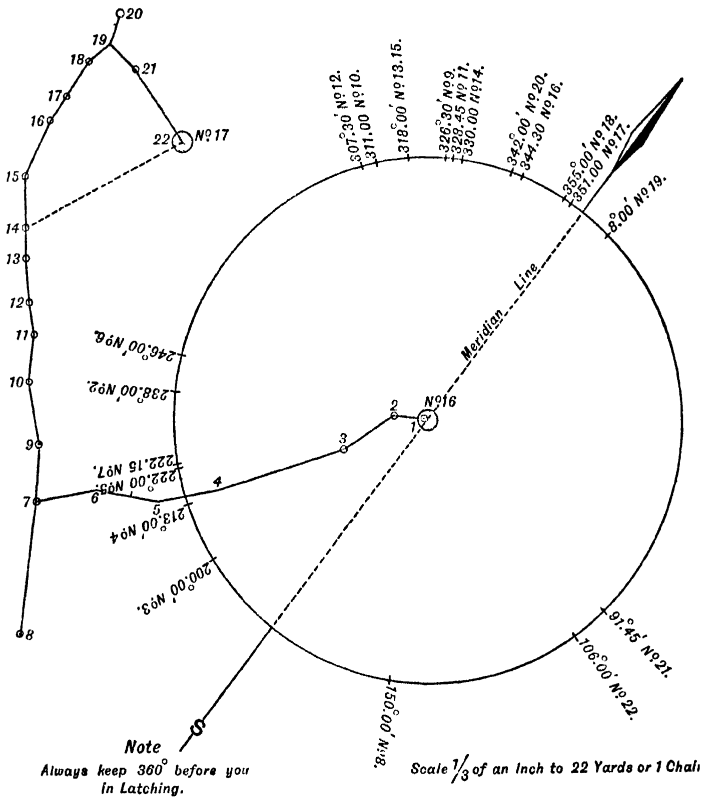
Latching or Dialling. (Merrett.)

"Latching" or "dialling" is a term used by miners when an underground survey is required of the course that has been excavated from one shaft of the mine to another. This survey is then transferred to the estate plan, by the guidance of the position of the shafts, which are accurately shown on both surveys. By reference to Fig. 35, which is an actual survey, it will be seen that the lengths are taken by the chain or tape in links, and the angles are taken by the needle or magnetic meridian with a circumferator, called by miners a "dial." The legs of this instrument are made with a screw joint in the middle. It has an extra set of points to screw on when the mine workings are low roofed. The survey commences at shaft No. 16, and is carried to shaft No. 17. The chain lines and angles are all plotted from that point. The circle shows the protractor with the meridian line through the centre, and all the angles marked thereon for

Latching—continued.

plotting. The "field-book" as it were, is on the margin, containing only the numbers, lengths, and angles. Great accuracy must be observed in taking the angles and lengths.

Fig. 35.

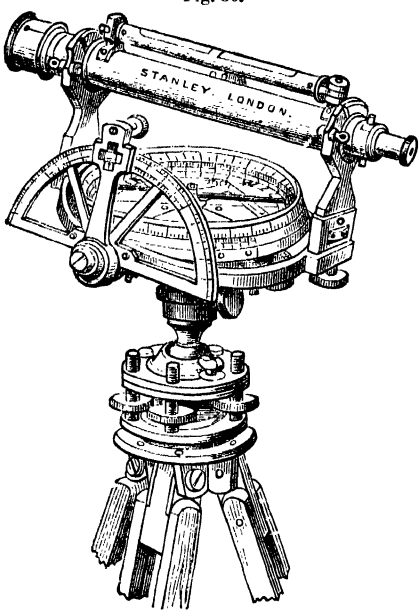


Latching or Dialling.

Surveying Instruments.

When minerals of value are found in a new country a survey is generally made, and plans drawn up upon which angles are secured for the future working. The instruments used for such surveys were generally of a class adapted to be used above or under ground. Mr. Stanley in his excellent practical work on surveying instruments* defines the qualities that a mining-survey instrument should possess, as follow:— 1. That there shall be means provided for shortening the tripod to work in strata of small depth. 2. That the instrument shall be low and compact in itself, that the head of the surveyor may be placed above it, if possible, even in shallow workings. 3. That great extent of adjustment of the compass-box to horizontality shall be given in the construction of the instrument, on account of the difficulty frequently of extending the tripod legs in close workings and from inclination of floor. 4. That it is desirable that the telescope, if there is one to the instrument, shall, besides taking nearly horizontal angles, take also a vertical position, to be able to sight lines from top to bottom of a shaft, or *vice versâ*. The illustration is of one of the best form of mining dials, for which we give Mr. Stanley's description.

Fig. 36.



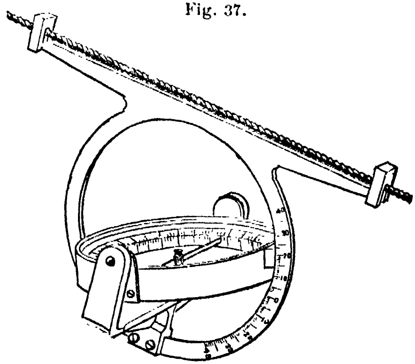
Improved Miners' Dial.

Improved Miners' Dial.—The illustration, Fig. 36, is the form of dial now generally approved. The telescope when this is used is supported in Y's; but the whole of the Y arrangement can be detached by loosening the two milled heads placed under the Y's, and the telescopic arrangement be replaced by extended open

* E. & F. N. Spon, 1890.

Instruments—continued.
sights. These are not shown in the engraving. The horizontal circle, instead of being placed in the interior of the box, is placed on the exterior rim, and reads with two verniers—not for correction, but for convenience of reading in different positions. The compass is divided upon the upper surface of the step to degrees, and in the same manner on the interior cylindrical surface of the step. This last often permits the compass to be read in a close working when the upper surface could not either be lighted or sighted. The plane of the compass is divided to 10° as usual. The compass adjusts by clamp and tangent motion. The axis of the instrument is supported upon a ball and socket arrangement for roughly bringing the compass to level, and a parallel plate adjustment for final setting. The ball is fixed by clamping a pair of plates together by thumb-screws. Each plate is hollowed in the centre to hold nearly half the ball. When fixed, the instrument is found to be very rigid. The tripods, not shown, have sliding fittings, which will clamp to any height from 2 feet 6 inches to 4 feet, which is a much better and more portable arrangement than the old form of loose pieces screwed together.

Fig. 37.



Stanley's Hanging Dial.

For close much-inclined mineral veins the hanging compass is found to be of the greatest utility. The illustration, Fig. 37, is Mr. Stanley's modification of this instrument. The compass is suspended from a copper wire or cord in any position where the two ends of the cord may be fixed or held. Where the inclination is great, a knot is made or a clamp fixed on the cord to prevent the instrument slipping down. The compass is balanced on centres, so that it takes its own level position by gravitation, and being suspended in a divided ring, inclination may be read off at the same time as taking the bearings of the line. When the cord is in the centre of the line this is taken correctly, but it will more frequently happen that observation can only be made near the ends of the line. When this is the case the mean of observations at each end of the line may be taken, or if one end observation only can be taken a small allowance may be made for the sag of the line. The instrument is made in two sizes, 5 inches and 3 inches, the last being a very light instrument to carry.

OCK

Table 126.—*Order of Superposition of British Rocks, showing the Systems, Formations, Groups of Strata, Characteristic Rocks, Prevalent Minerals, Typical Fossils.* (Readwin).

GEOLOGY.				MINERALOGY.	PALÆONTOLOGY.
SYSTEMS.	FORMATIONS.	GROUPS OF STRATA.	CHARACTERISTIC ROCKS.	PREVALENT MINERALS.	TYPICAL FOSSILS.
POST-TERTIARY.	RECENT.	The deposits of rivers, lakes, and seas 1	Soils, silt, sand, gravel, shingle, brick-earth, *alluvium*	Calc-tuff, Bog-Iron Ore, Amber, Gold, Platinum 1	Fossils of existing species. Human remains
CAINOZOIC.	PLEISTOCENE.	Drift and Glacial beds .. 2	Gravel, sands, brick-earth, old cave deposits	Flint 2	Shells of living species, Ox, &c. [*Flint implements.*]
	PLIOCENE.	Mammaliferous, or Norwich crag 3	Beds of shelly clay, sand, loam, layers of shingle, &c.	Disseminated Iron Oxide. 3	Mastodon, Mollusca
		Red crag of Norfolk and Suffolk.. 4	Ferruginous shelly sand and loam	Phosphatic Nodules 4	Bones and Teeth of Mammalia, Marine Shells
		Coralline crag of Suffolk .. 5	Whitish shelly sand, flaggy shell beds	Iron Oxide, Amber, Aragonite 5	Sponges, Polyzoa, Echinodermata. Shells
TERTIARY.	MIOCENE.	Leaf-beds of Mull, and ash-beds of Antrim.. 6	Leaf and ash beds, basalt	Lignite, Iron Ore 6	Plant remains
		Hempstead beds, Bovey Tracy clays, &c. 7	Marine and freshwater sands and clays	Lignite, Ironstone, Pyrites, Amber.. 7	Fluvio-Marine Shells and Plant remains
	EOCENE. Upper.	Bembridge beds 8	Marine and freshwater limestone, marls, and clays	Gypsum, Calcite, Iron Oxide 8	Land Shells, Turtles, Palæotherium
		Osborne, St. Helen's, and Headon beds 9	Marine and freshwater beds, alternating	Lignite, Clay-Ironstone .. 9	Marine Mollusca
	Middle.	Bagshot beds, Bracklesham beds.. 10	Sands and clay, with foliated marls	Oxide of Iron, Flint, Glass-house Sand 10	Marine Mollusca, Nummulites
	Lower.	London clay and Bognor beds 11	Brown and bluish grey clay, with septaria	Sulphide and Carbonate of Iron: Septaria: Selenite 11	Mammalia, Shells, Fishes, Chelonians, Crocodiles
		Oldhaven, Woolwich, and Reading beds 12	Freshwater sands, pebble beds, clay, rolled flints from chalk	Sulphide and Carbonate of Iron; Allophane 12	Fluvio-Marine Mollusca, Fishes
		Thanet sands 13	Sands with concretionary masses of sandstone	Oxide of Iron, occasionally 13	Marine Mollusca

Table 126—*continued.*

	GEOLOGY.			MINERALOGY.	PALÆONTOLOGY.
SYSTEMS.	FORMATIONS.	GROUPS OF STRATA.	CHARACTERISTIC ROCKS.	PREVALENT MINERALS.	TYPICAL FOSSILS.
MESOZOIC. SECONDARY.	CRETACEOUS *Upper.*	Upper chalk beds, with flints 14	Soft white chalk, beds, and nodules of flint	Flint, Pyrites, Hornstone, Allophane 14	Marine Shells, Echinodermata, Sponges, Fishes
		Lower chalk beds, without flints 15	Hard chalk, less white, generally without flints	Pyrites. Ochreous concretions 15	Sponges, Cephalopoda, Foraminifera
		Chalk-marl or grey chalk beds 16	Soft grey chalk, very clayey, sometimes indurated	Phosphate of Lime (Coprolites) 16	Shells, Echinodermata, Saurians
	Middle.	Upper Green Sand 17	Siliceous and calcareous sand, nodules of chert	Siliceous concretions, Firestone, Chalcedony 17	Ammonites, Sponges, Echinoderms, Marine Shells
		Gault 18	Bluish marly clay, green grains, and sand	Phosphate of Lime (Coprolites), Pyrites, Selenite .. 18	Marine Shells, Belemnites, Ammonites, Saurians
	Lower.	Lower Green Sand, or Shanklin sand 19	Green or ferruginous sands, layers of cherty limestone	Ironstone, Fullers' Earth.. 19	Sponges, Cephalopoda, Crustacea
		Weald clay and Hastings beds 20	Blue and brown strong clay, beds of shelly limestone	Petworth or Sussex Marble, Calcite 20	Reptiles (Iguanodon), Fishes, Plants
	JURASSIC. *Upper*, or Portland Oolite.	Purbeck limestone 21	Estuary limestones, clays and sands alternating	Calcite 21	Fishes, Mammalia, Insects, Reptiles, Trees, &c.
		Portland beds 22	Oolitic and shelly limestone, layers of chert and sand	Chert, Calcite, Quartz-Crystals, Lignite 22	Marine Shells, Corals, Saurians
		Kimmeridge clay 23	Dark blue or black slaty clay, bituminous shale	Bitumen, Gypsum, Lignite, Pyrites, Alum-stone .. 23	Marine Shells, Ammonites, Belemnites, Saurians
	Middle, or Oxford Oolite.	Upper calcareous grit and clays 24	Sands. Beds and nodules of calcareous grits	Calcite, Scarbroite, Jet, Ironstone 24	Ammonites, Marine Shells
		Coral Rag and coralline Oolite 25	Coarse oolitic limestone, with many corals	Calcite, Pyrites 25	Corals, Marine Shells
		Lower calcareous grit and Limestone 26	Sands. Beds and nodules of calcareous grits	Calcite, Pyrites, Hematite 26	Ammonites, Marine Shells
		Oxford clay 27	Dark blue clay, slaty and bituminous	Selenite, Pyrites.. 27	Fishes, Shells, Belemnites, Ammonites, Saurians
		Kelloway rock 28	Ferruginous coarse calcareo-siliceous limestone	Oxide of Iron, Calcite .. 28	Marine Shells, Ammonites, Belemnites
	Lower, or Bath Oolite.	Cornbrash 29	Coarse rubbly limestone, layers of clay, &c.	Oxide of Iron, Calcite .. 29	Marine Shells, Ammonites
		Forest marble and Bradford clay 30	Coarse shelly oolitic limestone and clay	Calcite, Chalcedony 30	Ammonites, Shells, Brachiopoda, Encrinites
		Bath, or great Oolite.. .. 31	Thick-bedded oolitic limestone, freestone	Roe-stone, Pisolite 31	Corals, Shells, Nautili, Ammonites

Table 126—*continued.*

GEOLOGY.				MINERALOGY.	PALÆONTOLOGY.
SYSTEMS.	FORMATIONS.	GROUPS OF STRATA.	CHARACTERISTIC ROCKS.	PREVALENT MINERALS.	TYPICAL FOSSILS.
MESOZOIC. SECONDARY.	JURASSIC. Lower, or Bath Oolite.	Stonesfield slate 32	Oolitic shelly siliceous limestone, slaty	Pyritous Coal 32	*Mammalia*, Reptiles
		Fullers' earth 33	Limestone and clay, containing Fullers' earth	Fullers' Earth, Gypsum .. 33	Marine Shells, Echinodermata
		Inferior Oolite 34	Coarse shelly limestone, or freestone	Calcite, Iron Ore 34	Marine Shells, Brachiopoda, Echinodermata
	LIAS.	Upper Lias shale.. 35	Dark-blue clay, alum shale, ferruginous sand	Bitumen, Alum, Jet 35	Marine Shells, Fishes, Saurians
		Middle Lias marlstone .. 36	Calcareous laminated sandy limestone, iron beds	Nodules of Ironstone, Septaria 36	Marine Shells, Ammonites, Belemnites
		Lower Lias, clays and limestone beds 37	Clay and limestone, alternating	Bitumen, Pyrites, Phosphate of Lime 37	Saurians, Cephalopoda
	RHÆTIC.	Penarth beds and white Lias 38	Estuarine (partly) shales, bone beds, &c.	Slates, Calcite, Cotham Marble 38	Bone-beds, Fishes, Shells, *First Mammalia*
	TRIASSIC. New Red Sandstone.	Keuper marl 39	Marls and sandstones, with rock salt and gypsum	Gypsum, Rock Salt 39	Few Fossils. *Foot-prints*, Estheria, Fish
		Dolomitic conglomerates of the Mendips 40	Red and white salty sandstone, conglomerates with gypsum	Agates, Gypsum, Iron and Zinc Ores, Dolomite .. 40	
		Bunter sandstone and conglomerates.. 41	Red clay and sand conglomerates and breccia	Hematite, Calcite 41	Few Fossils. Saurians
PALÆOZOIC. PRIMARY.	PERMIAN.	Magnesian limestone .. 42	Fawn-magnesian limestone, sometimes brecciated	Ores of Lead, Copper, Zinc 42	Marine Mollusca, Saurians
		Lower new red sandstone, conglomerates, marl .. 43	Highly ferruginous sands, marls, and conglomerates	Much Oxide of Iron, Agates 43	Marine Remains, Plants
	CARBONIFEROUS.	Coal measures (Ardwick, Pennant, and Gannister) 44	Coal-beds, with layers of shale or grit	Anthracite, Splint, and Cannel Coal, Ironstone .. 44	Marine and Freshwater Mollusca, Ferns, Conifers
		Millstone grit and Yoredale Series 45	Siliceous sandstones and conglomerates. Fire-clay	Coal, Ironstone 45	Plants and Marine Mollusca
		Carboniferous limestone .. 46	Compact crystalline limestone and shales	Fluor, Ores of Lead, Zinc, Antimony, Iron 46	Marine Shells, Corals, Bryozoa, Cephalopoda
	DEVONIAN. Old Red Sandstone.	Upper Devonian, Marwood, Petherwin limestone .. 47	Yellow, white, and red sandstones and conglomerates	Agates, Ores of Tin, Copper, and Lead and Zinc 47	Corals, Brachiopoda, Ganoid Fish and Plants
		Middle Devonian, Limestones and Shales 48	Green and red shales and sandstones, with cornstones	Iron Ore, Calcite, Marble.. 48	Corals, Brachiopoda, Ganoid Fish and Plants
		Lower Devonian, Linton and Fowey beds 49	Red shales, sandstones, and conglomerates. Tilestones	Firestone, Chalcedony, Ores of Copper and Tin 49	Marine Mollusca, Ganoid Fish and Plants

Table 126—*continued.*

		GEOLOGY.		MINERALOGY.	PALÆONTOLOGY.
SYSTEMS.	FORMATIONS.	GROUPS OF STRATA.	CHARACTERISTIC ROCKS.	PREVALENT MINERALS.	TYPICAL FOSSILS.
PALÆOZOIC.	SILURIAN.	Upper Ludlow shale—Ludlow Rocks 50	Indurated shaly micaceous sandstones	Barytes, Calcite, Copper, Lead and Manganese Ores 50	Mollusca, Brachiopoda, Graptolites, Fish
		Aymestry limestone—Ludlow Rocks 51	Impure crystalline limestone	Calcite, Copper, Lead and Manganese Ores 51	Marine Mollusca
		Lower Ludlow shale—Ludlow Rocks 52	Indurated shaly micaceous limestone	Calcite, Copper, Lead and Manganese Ores 52	Marine Mollusca, Trilobites
	Upper.	Wenlock and Dudley limestone—Wenlock Rocks .. 53	Grey limestone, clayey shale in thick beds	Calcite, Copper, Lead and Manganese Ores .. . 53	Brachiopoda, Encrinites, Bryozoa, Crinoids
		Wenlock shale and Denbigh grit—Wenlock Rocks .. 54	Shales and coarse siliceous sandstones, slates	Calcite, Copper, Lead and Manganese Ores 54	Marine Mollusca
PRIMARY.		Woolhope and Barr Limestone—Wenlock Rocks .. 55	Crystalline limestones and shales alternating	Calcite, Copper, Lead and Manganese Ores 55	Corals, Trilobites, Graptolites
		Tarannon shales 56	Red shales and sandstones	Calcite, Copper, Lead and Manganese Ores 56	Marine Mollusca
		Upper Llandovery (May Hill Sandstone) 57	Fine-grained sandstones and conglomerates	Oxide of Iron, Copper, Lead and Manganese Ores .. 57	Marine Shells, Corals, Trilobites
		Lower Llandovery sandstone 58	Green and purple sandstones and shales	Ores of Lead and Copper, Gold 58	Marine Shells, Corals, Trilobites
		Caradoc and Bala beds .. 59	Shales and sandstones	Ores of Lead, Copper and Iron, Gold, Silver 59	Corals, Trilobites, Brachiopoda
	Lower.	Llandeilo Flags (upper and lower) 60	Black laminated flagstones and limestones	Ores of Lead, Copper, and Iron, Barytes 60	Trilobites, Brachiopoba, Graptolites
		Tremadoc slates? Graptolite schists 61	Black schists, slates	Ores of Lead, Copper, and Iron 61	Graptolites, Brachiopoda
		Lingula flags (upper and lower). Menevian Beds 62	Black schists and dark grey flagstones	Ores of Lead, Copper, and Zinc, Gold, Silver 62	Brachiopoda, Trilobites, Lingulellæ
	CAMBRIAN.	Harlech and Llanberis slates, and Longmynd grits .. 63	Conglomerates, sandstones, shales, slates, porphyry	Barytes, Ores of Copper, Silver and Lead, Gold .. 63	Fucoids, Trilobites
	PRE-CAMBRIAN.	St. David's and Anglesea Rocks 64	Conglomerates, schists, slates, and felsite	Quartz, Graphite, Apatite, Iron & Copper Ores, Gold 64	Worm-tubes
AZOIC.	METAMORPHIC.	Gneiss, &c., rudely stratified 65	Gneiss, quartzite, slates, hornblendic gneiss, serpentine	Garnet, Asbestos, Ores of Tin, Lead & Copper, Gold 65	No fossils *yet* discovered
	IGNEOUS.	Granite, &c., unstratified .. 66	Granite, syenite, basalt, trachyte, gabbro, diabase	Quartz, Felspar, Talc, Actinolite, Hornblende, Albite, Ores of Tin & Lead, Gold 66	No fossils *yet* discovered

GEOLOGICAL MAPS.

GEOLOGICAL SURVEY MAP SIGNS.

(*a*) Connected with Stratification.

+	Horizontal.
	Vertical (longest line on the strike).
×	Undulating.
	Contorted.
	Highly inclined
	Undulating
	Contorted
	(Highly inclined, Undulating, Contorted:) With general dip in the direction of the arrow.
	Anticlinal axis.
	Synclinal axis.
	Dip from observation (with No. of degrees, thus 5°).
	Dip from information.
/	Cleavage.
⊙	Limestone quarries.
S. Q.	Slate quarries.

Interrupted Lines = A doubtful or drift-covered boundary.

White Lines = Faults at the surface.

Yellow Lines = Faults underground.

Thick Black Lines = Coal crops. When doubtful, lines interrupted.

○	Bore hole.
⊖	Mine shaft.
DH	Day hole (entrance to adit).
═══	Colliery levels.

Survey Signs—continued.

(*b*) Connected with Glacial Drift.

	Roches moutonnées.		
	,, ,,	striated	Direction of Ice-flow not apparent.
	Flat surface	,,	
	Roches moutonnées	,,	Showing direction of Ice-flow.
	Flat surface	,,	

(*c*) Indicating Ores of Metals.

☉	Gold.	☽	Silver.
♀	Copper.	♃	Tin.
♄	Lead.		Manganese.
♂	Iron.		Zinc.

Gold Lines = Mineral Veins.
Gold Dots = Stream Tin.
Gold Rings = Pipe Veins.

MINERAL VEINS.

Table 127.—*Dip, Depth, and Thickness of Beds.* (Penning.)

Amount of Dip.	Co-tangent of Angle of Dip.	Approximate Proportionate Incline.	Yards of Rise or Fall in 1 mile.	Vertical Depth from Surface in a Horizontal Distance of 100.	Thickness of Beds at right angles to Plane of Stratification.
°					
0	Infinity.				
1	57·29	1 in 57	31	1·75	1·75
2	28·6363	1 in 28½	61	3·5	3·5
3	19·0811	1 in 19	92	5·25	5·25
4	14·3007	1 in 14½	126	7·	7·
5	11·4301	1 in 11½	155	8·75	8·75
6	9·5144	1 in 9½	185	10·5	10·5
7	8·1443	1 in 8	217	12·5	12·25
8	7·1151	1 in 7	249	14·	13·75
9	6·3138	1 in 6½	279	16·	15·75
10	5·6713	1 in 5½	314	17·5	17·25
11	5·1445	1 in 5	345	19·5	19·25
12	4·7046	1 in 4½	391	21·25	20·75
13	4·3315			23·25	22·5
14	4·0108	1 in 4	440	25·	24·
15	3·7321			26·75	25·5
16	3·4874	1 in 3½	..	28·5	27·
17	3·2709			30·	28·25
18	3·0777	1 in 3	..	32·25	30·25
19	2·9042			34·5	32·
20	2·7475			36·5	33·5
21	2·6051	1 in 2½	..	38·5	35·
22	2·4751			40·	36·
23	2·3559			42·25	37·75
24	2·2460			44·5	39·5
25	2·1445			46·75	41·25
26	2·0503	1 in 2	..	47·75	41·75
27	1·9626			51·	44·25
28	1 8807			53·25	45·75
29	1·8040			55·5	47·25
30	1·7321			58·	49·
31	1·6643			60·25	50·5
32	1·6003			62·5	51·75
33	1·5399			65·	53·25
34	1·4826	1 in 1¼	..	67 5	54·75
35	1·4281			70·	56·25
36	1·3764			72·5	57·75
37	1 3270			75·25	59·5
38	1·2799			78·	61·

Table 127—*continued.*

Amount of Dip.	Co-tangent of Angle of Dip.	Approximate Proportionate Incline.	Yards of Rise or Fall in 1 mile.	Vertical Depth from Surface in a Horizontal Distance of 100.	Thickness of Beds at right angles to Plane of Stratification.
°					
39	1·2349			81·25	63·
40	1·1918			84·	64·5
41	1·1504			87·	65·75
42	1·1106			90·	67·75
43	1·0724			93·	69·25
44	1·0355			96·	70·25
45	1·	1 in 1	..	100·	71·
46	·9657			104·	72·
47	·9325			107·	73·25
48	·9004			111·	74·25
49	·8693			115·	75·5
50	·8391			119·	77·
51	·8098	..	..	123·	78·
52	·7813	..	..	128·	79·
53	·7536	..	..	133·	80·
54	·7265	..	..	137·	81·
55	·7002	..	..	143·	82·
56	·6745	..	..	150·	83·
57	·6494	..	..	154·	83·25
58	·6249	..	..	161·	84·5
59	·6009	..	..	166·	85·5
60	·5774	..	..	172·5	86·5
61	·5543	..	..	180·	87·
62	·5317	..	..	188·	88·
63	·5095	..	..	200·	89·
64	·4877	..	..	205·	90·
65	·4663	..	..	213·	90·5
66	·4452	..	..	224·	91·
67	·4245	..	..	235·	91·5
68	·4040	..	..	250·	92·
69	·3839	..	..	260·	93·
70	·3640	..	..	275·	94·
71	·3443	..	..	300·	94·5
72	·3249	..	..	308·	95·
73	·3057	..	..	327·	95·5
74	·2867	..	..	345·	96·
75	·2679	..	..	370·	96·5
76	·2493	..	..	400·	97·
77	·2309	..	..	433·	97·5
78	·2126	..	..	476·	97·5
79	·1944	..	..	515·	98·
80	·1763	..	..	570·	98·5
81	·1584	..	..	633·	98·5
82	·1405	..	..	714·	99·
83	·1228	..	..	813·	99·
84	·1051	..	..	1000·	99·5
85	·0875	..	..	1140·	99·5
86	·0699	..	..	1430·	99·5
87	·0523	..	..	1912·	100·
88	·0349	..	..	2865·	100·
89	·0175	..	..	5714·	100·
90	·0000	..	..	—	100·

Dip, Depth, and Thickness.

Ex. 1. The outcrop, in a level district, of a definite bed is observed in a quarry, where it is found to dip E. at an angle of 14°. This bed would be found, if its dip remains unaltered, 100 yd. east from the quarry at a depth of 25 yd. = 75 ft.; the beds above it would have an actual thickness of 24 yd. = 72 ft.

Ex. 2. The outcrop of the same bed with the same dip is observed in a district where the surface rises in the direction of the dip at an angle of 10°. The bed would be found, 100 yd. E. at a depth of 75 ft., as before, plus the rise in the ground between, which in 100 yd., at the rate of 314 yd. in a mile, is $17\frac{2}{3}$ yd. = 53 ft.:—75 + 53 = 128 ft. If the ground were falling, instead of rising, at an angle of 10° in the direction of the dip, the bed would be met with at 75 − 53 = 22 ft.

Ex. 3. A bed or formation is known to be 36 yd in thickness, and to dip at an angle of 14°. In 100 yd. of outcrop it would, at that dip, have a thickness of 24 yd. only, therefore its outcrop is (24 : 36 : : 100) : 150 yd.

Ex. 4. The thickness is known to be 36 yd. as before, and the level outcrop 150 yd. In 100 yd. ($\frac{2}{3}$ of 150), the thickness would be 24 yd., which corresponds to a dip of 14°.

Ex. 5. The dip of the bed is 14°, its outcrop 150 yd.; in 100 yd. at 14° the thickness would be 24 yd., therefore in 150 it is 36 yd.

MINERAL VEINS: *Contents of Veins.*

A vein of ore 1 in. thick, 6 ft. long, and 6 ft. high (= 1 sq. fathom) will measure 3 cub. ft.; 2 in. thick = 6 cub. ft. per fathom; and so on.

Table 128.—*Weights of Ores* 1 *in. thick per sq. fathom* (*i. e. per* 3 *cubic ft.*).

	lb.		lb.
Antimony, grey oxide	843	Iron, magnetic	1016
Barytes	750	„ pyrites	912
Cobalt, pyrites	937	„ specular	912
Copper, carbonate (malachite)	712	Lead, carbonate	1200
„ grey	900	„ sulphide (galena)	1406
„ native	1668	Nickel, arsenical	1406
„ pyrites	787	Silver, native	1875
„ red	1106	Tin, oxide	1256
„ vitreous	1050	„ pyrites	825
Gold, native	3281	Uranium, oxide (pitchblende)	1312
Iron, arsenical	1068	Zinc, red oxide	1012
„ hæmatite	750	„ sulphide (blende)	750

The above figures × 9 = weights per cub. yd.

Table 129.—*Weights of Rocks per cub. ft.*

	lb.		lb.
Basalt	187	Limestone, Portland	131
Chalk	143	Marble	168
Clay	125	Sand	120
Granite	164–172	Sandstone	130–157
Gravel	120	Shale	162
Grit	131	Shingle	90
Limestone	156–175	Slate	175–180
" Bath	112	Trap	170
" magnesian	178	York flags	143

MINERAL VEINS: *Examination of Wall Rocks of Auriferous Fissures.* (Attwood.)

The mere inspection of the outer surface of a rock, viewed as an opaque object, does not give such correct information as that obtained when the examination is made by transmitted light, and with the aid of the microscope; yet, if the examination is properly conducted, it will afford all the necessary information required by the miner to enable him roughly to distinguish the character of the enclosing rocks of most auriferous fissures, especially if the rocks should be of a coarse texture.

In the macroscopical investigation of rocks, those parts of the mineral constituents discernible by the naked eye, or by the aid of a common magnifier, can be easily studied, with reference to crystalline form, cleavage, colour, lustre, streak, hardness, solubility in acids, magnetic properties, &c. The specimen of rock selected for examination should have a good fresh surface of fracture, and be free from decomposition; size, about 3 by 4 in. across, and 1½ in. through. With a trimming hammer, prepare the 1½ in. face, or dress it as even as possible; then procure an iron plate, with a smooth face about 10 in. square and ½ in. thick, on which put emery powder No. 80 and water; rub the prepared face of the specimen upon it till it is smooth enough to polish. This can be done by getting a piece of thick glass, about same size as the iron plate, on which put fine emery and water, and again rub the specimen till you obtain a fine polish. When polished, heat the specimen on a stove so that you can barely handle it, and when in that condition rub Canada balsam over *half* the polished surface. When cold it will harden so that it can be handled without injury. A small fragment may be broken from the unpolished end to try its specific gravity, magnetic properties, and also for acid tests.

The following implements will be found sufficient for this simple mode of investigation:—

1. A common magnifier mounted in horn, that being lighter than metal; it should have three powers, and be set in a spectacle frame with screws, so that the different powers can be easily changed.

Wall Rocks—continued.

2. A small bar magnet, and also a magnet needle freely suspended or supported.
3. A small unglazed porcelain streak plate.
4. A bottle of hydrochloric acid, with a fine glass rod attached to the stopper.
5. A dressing hammer, with the head about 3 in. long; one end with a face ½ in. square, and the other chisel shaped.
6. A pocket micrometer, same as made by Lietz, San Francisco.
7. A piece of flat iron, 10 in. square and ½ in. thick.
8. A piece of thick glass, 10 in. square, and a few lb. of coarse and fine emery.
9. Scale of hardness.

The best mode of determining the hardness is to have the minerals forming the scale of hardness mounted, something like the writing diamond. Break, for instance, the corundum, topaz, &c., into small fragments, and after selecting those with fine, sharp points, proceed to mount them as follows:—

Take a piece of brass wire 3 in. long by ⅛ in. diameter, and with a file make small notches on one end of the wire; then take "lapidary's cement," warm the end of the wire with a spirit-lamp or candle, and melt some of the cement on to it. By wetting the finger and rubbing the cement while warm, it can be moulded into any shape desired. With a small pair of pliers take the small fragments of corundum, &c., heat one end of the corundum, and then place it in the cement. If this be properly done, it will answer just as well as if set in metal, with this advantage, that you can renew it at any time in a few moments.

In addition to the implements named, a small collection of the commoner types of rocks should be procured, and prepared with polished sides, after the manner before described.

The specimens of igneous rocks should consist of granite, syenite, diorite, gabbro, diabase, dolerite, and basalt, and of small bottles with fragments of the different felspars, showing character and cleavage; orthoclase (potash felspar), albite (soda), anorthite (lime), labradorite (lime soda); also small pieces of hornblende and augite.

The triclinic felspar may be distinguished from monoclinic, *e.g.* oligoclase or labradorite from orthoclase, by the presence of fine parallel striæ along the surface of certain of the cleavage planes. Hornblende crystals have generally a fibrous structure, by which they may often be recognised from augite crystals.

It will also be necessary to have a few specimens of metamorphic, crystalline schists, sedimentary and fragmental rocks. With the small collection of the already named characteristic rocks for comparison, the rough determination of hand specimens of enclosing rocks may easily be arrived at. The coating of Canada balsam shows the structure and crystalline character much better than the ordinarily polished surface, so that the tests for hardness, &c.,

Wall Rocks—continued.

should be applied only to the polished surface. By having the lenses set in spectacle frames both hands are at liberty, one to hold the rock, the other to use the scale of hardness, or to apply the fine glass rod dipped in acid to try if any of the component parts of the specimen effervesce. These tests for comparison can be applied to those types in the collection which resemble the one being tested. The magnetic properties can be tested with a freely suspended magnetic needle, or by breaking a portion of the rock into small fragments, washing it in a Latea, and then applying the bar magnet to the heavier particles. The size of the crystals may be measured with a pocket micrometer. The macroscopic inspection of rocks made by cutting large slices and polishing their faces is strongly to be recommended to all miners and prospectors as of the highest importance.

Table 130.—*Igneous Rocks classified, primarily, according to their Mineralogical Composition; and, secondarily, according to their Intimate Structure.* (Prof. Bonney.)

	Matrix Wholly Crystalline.	Matrix Semi-Crystalline.	
1. Orthoclase felspar.			
a. Quartziferous ..	Granite	Quartz-felsite ..	Quartz-trachyte.
b. Quartzless ..	Syenite	Orthoclase-felsite, minette.	Sanidin - trachyte, pitchstone, and obsidian.
2. Plagioclase felspar.			
a. Oligoclase, sometimes with quartz	Diorite	Porphyrite	Andesite.
b. Labradorite, or an allied mineral or quartz.	Gabbro, diabase, dolerite, basalt.	Some basalts ..	Tachylite.

Indicative Plants.

From very early times it has been noticed that the soil overlying mineral veins is favoured by special vegetation, and though the occurrence of such vegetation cannot be taken as an infallible indication of the existence of such veins, it will be interesting to record the results of past observations, so that they may serve for a guidance to further observation in future.

Iron.—A vein of iron ore near Siegen, Germany, can be traced for nearly 2 miles by birch trees growing on its outcrop, while the remainder of the country is covered with oak and beech.

Lead.—The "lead plant" (*Amorpha canescens*) is said by prospectors in Michigan, Wisconsin, and Illinois to be most abundant in soils overlying the irregular deposits of galena in limestone.

Indicative Plants—continued.

It is a shrub 1–3 ft. high, covered with hoary down; the light blue flowers are borne on long spikes, and the leaves are arranged in close pairs on stems, being almost devoid of footstalks.

Gum trees or trees with dead tops, as also sumac and sassafras, are observed in Missouri to be abundant where "float" galena is found in the clays.

Limestone.—The beech tree is almost invariably prevalent on limestone, and detached groups of beech trees have led to discoveries of unsuspected beds of limestone.

Phosphate.—The phosphate miners in Estremadura, Spain, find that the *Convolvulus althæoides*, a creeping plant with bell-shaped flowers, is a most reliable guide to the scattered and hidden deposits of phosphorite occurring along the contact of the Silurian slates and Devonian dolomite.

Silver.—In Montana, experienced miners look for silver wherever the *Eriogonum ovalifolium* flourishes. This plant grows in low dense bunches, its small leaves coated with thick white down, and its rose-coloured flowers being borne in clusters on long smooth stems.

Zinc.—The "zinc violet," *Galmeiveilchen*, or *Kelmesblume* (*Viola calaminaria*) of Rhenish Russia and neighbouring parts of Belgium, is there considered an almost infallible guide to calamine deposits, though in other districts it grows where no zinc ore has been found. In the zinc districts its flowers are coloured yellow, and zinc has been extracted from the plant. The same flower has been noticed at zinc mines in Utah.

Ore Deposits.

The primary source from which metalliferous veins have been derived, and the causes which determined the peculiar metal or metals in each case, are matters about which we know nothing. But the manner in which these deposits have been formed comes within the bounds of reasonable conjecture, and has an important bearing upon the commercial value of the deposit, especially as regards its bulk and permanence.

There is abundant evidence in favour of the opinion that all the principal accumulations of useful ores are due to the precipitation of material collected by water in its passage through rocks at various depths, the mineral being very sparsely and widely distributed, dissolved by the water under the influence of considerable heat, and subsequently concentrated and precipitated in favourable situations. These latter were less likely to have been large cavities than narrow spaces, though occasionally there may have been wide areas awaiting the influx of vein matter. But it seems quite as likely that where large veins occur these are in great measure composed of altered country rock, and owe only a small portion of their contents to extraneous sources. Assuming this origin of metallic veins to be correct, then a knowledge of the geological

Ore Deposits—continued.
structure of the district, as bearing upon the formation of the water passages which introduced the metalliferous solutions, is of great significance to the mining engineer.

This subject has been very thoroughly dealt with by S. F. Emmons, of the United States Geological Survey, and the following remarks are condensed from his published papers. The three principal structural conditions which would produce natural water-passages in the rocks forming the earth's crust are:—

(*a*) Sedimentation or bedding.
(*b*) Intrusion of eruptive masses.
(*c*) Dynamic movements producing fractures across rock-masses of differing origin or composition.

(*a*) By the first of above causes, by the deposition of alternating strata of varying degrees of permeability, or by successive flows of igneous rocks, natural channels will be afforded parallel to the stratification or bedding planes, and more or less coincident with them according to the nature of the material of which the bounding beds are formed.

These primary water-channels along bedding-planes may be interrupted by either of the two causes *b c*.

(*b*) Eruptive dikes or cross-cutting intrusive bodies of any form may interpose relatively impermeable masses across their course, or intrusive bodies, running parallel with the bedding, may render the plane of contact a more ready water passage than it otherwise would have been.

(*c*) The interruption to these primary water-channels resulting from the varied forms of rock-fracture caused by dynamic movements are manifold and numerous.

The greatest number of underground water-channels, though perhaps not those carrying the largest volumes of water, will be afforded by the multitudinous fractures in the crystalline or eruptive rocks, and in the older and more metamorphosed sedimentary strata.

Another possible class of division-planes in rocks are contraction-planes or joints, notably the prismatic joints of more recent eruptives. Contraction-planes must be confined to one rock-mass or bed, and cannot cross several of them, as do most mineral-bearing fissures. Also, as contraction-planes alone, there would have been no movement or pressure along them. Hence planes where evidences of movement or pressure are found cannot result from contraction alone.

Ore-deposits along bedding-planes.—Most ore-deposits are found in mountainous regions where eruptive and dynamic action has been energetic; consequently, deposits resulting from the flow of water along bedding-planes alone, unconnected with the other classes of water-channels, form but a small proportion of the whole. Moreover, deposition will take place more readily from a comparatively

Ore Deposits—continued.

sluggish than from a rapid flow; hence conditions that tend to retard the flow or cause a partial stagnation at a given point will favour precipitation at that point. Such would be the actual contact of an impervious stratum, *e.g.* a bed of clayey material—with a readily pervious one like a loose sandstone. Again, in plicated strata, points where by sharp folding the beds are closely compressed together—as on the side of the fold—are often found to carry large bodies of ore. The chemical composition of the different beds is also a most important factor. In some regions, where thin beds of limestone are scattered through considerable thicknesses of sandstone and shales, the ore is almost exclusively confined to the more readily attackable limestone.

Deposits along contact-planes.—Mineral-bearing solutions gathering in or flowing along the planes of contact of eruptive bodies with rocks through which they had been forced would have a tendency to deposit their contents along such planes, whatever the direction of their flow. If they were ascending currents, it may be conceived that they were coming from a hotter region, or from the vicinity of a larger and not so thoroughly cooled mass of igneous rock, where their solvent power was greater, to a cooler region in which this solvent power would be relatively less. If lateral or descending flows, gathering from the mass of one of the walls of the fissure, precipitation might be induced from the solutions thus brought in by a retardation or temporary stagnation of the flow, by dilution through mixing with other waters already circulating in the fissure, or by some chemical interchange resulting from contact with the other wall, if a rock of different chemical composition from that through which the solutions had been passing.

Contact-planes as defined above will more frequently be found to coincide or connect with planes of rock-fracture, since one can hardly conceive of sheets of eruptive rock being forced through existing rock-masses in the form in which we now find them, unless they had followed some already determined line of fracture, or at least of readiness to be forced open, and it is well known that eruptions of lava at the present day are generally preceded by earthquake shocks, which probably involve a very considerable shattering and fissuring of the earth's crust in the vicinity of the eruption.

Ore-deposits along contact-planes are very common. Of deposits along the contacts of dikes or cross-cutting bodies of eruptive rock, hence generally occupying a more nearly vertical position, abundant examples are found, most of which are commonly classed by the miner as fissure-veins, because of the prevailing prejudice in favour of the supposed greater value of that type of deposit. It may be that the whole mass of a narrow dike is impregnated with mineral, and thus constitutes the ore-body; but in the structural sense it is none the less a contact-deposit, since the deposit has been made by waters acting from the contact-planes outward.

Ore Deposits—continued.

Deposits along planes of rock-fracture or fissures produced by dynamic movements.—The most prominent and readily remarked of these rock-fractures are the great faults which have played so important a part in determining the orographic relief of our globe. The greatest of these faults often extend for miles in length, and the displacement of the opposed rock-masses on either side of the fault may amount to several thousand feet. Minor faults, or displacements which are found in infinite variety, especially in regions of great dynamic distubance, may not produce any readily apparent effect upon the surface-features, and yet may be recognisable as determining the flow of springs, or be detected by the underground workings of mines. They have been most thoroughly studied in the workings of coal-mines, where the importance of careful underground mapping is most generally appreciated, since the determination of the direction and amount of throw of such faults has an actual money-value. In all these rock-fractures the evidence of a movement of displacement, as disclosed by the discrepancy or want of correspondence in the adjoining walls, is usually very prominent. There are other and much more numerous rock-fractures, in which there is either no movement of displacement, or it is so slight as to be with difficulty detected. Among them certain classes are characterised by their frequency and their general parallelism in two or more co-ordinated directions, and at angles often approaching a right angle with each other.

Causes of Fracture.—It is hardly necessary to state that the force which produces the folding, faultings and rock-fractures, in short the mountain-building force, must be considered as a result of the secular construction of the earth's crust, the forces exerted resulting from the attempt of an already consolidated crust to fit itself more closely to a shrinking nucleus. Their effect is felt probably only upon a comparatively thin outer portion of the earth's crust: at any rate it is a very thin portion of this crust which comes under our observation. This crust may be conceived, therefore, as having been since its first formation in a condition of tension, a gradually increasing force which from time to time found its relief in earth-movements producing corrugations on its surface, and hence relative elevations along certain orographic lines, which from some reason or other were lines of least resistance or of weakness. Such lines, once determined, have been the scene of most marked expression of these constantly recurring movements of relief from tension. Closely connected with such movements have been the eruptions of igneous material, forced up from below, either from a region of permanent fusion of the material of the earth's crust, as was formerly most generally maintained, or, according to later views, from local reservoirs brought into a fused condition as a more or less direct result of these movements, by the disturbance of equilibrium between the various forces involved in the general condition of tension. Whatever their source, the eruptions of igneous rocks

Fractures—continued.
have unquestionably had a very close connection with orographic disturbances, and further have indirectly played an important part in the formation of most ore-deposits.

Observation teaches us that these successive periods of dynamic disturbance, or of mountain-building, must have been followed by periods of relative quiescence, during which the regions elevated into land-masses were worn down by atmospheric abrasion, and their comminuted débris carried into the adjoining oceans to form a new series of sedimentary beds. Each successive series of dynamic movements would involve not only this newer series, but also the older and already plicated and fractured series of rocks; and thus the structural conditions are found to be more complicated and more difficult to decipher, the older the rocks in which we have occasion to study them.

Common characteristics of compression-fractures.—There are three phases of structural evidence of rock-fractures and displacement resulting from compression, one or more of which characterise the various types of fissures carrying ore-deposits. These are:—

(*a*) Striations and "slickenside"-surfaces.

(*b*) Breccia or fragmentary material in the fissure itself, or zones of crushed or broken rock-material included between intersecting systems of fissures.

(*c*) A sheeting of the country-rock parallel with the main fracture: in other words, the occurrence of a system of minor fractures which divide the country-rock up into a system of approximately parallel plates or sheets. The distance between these parallel fractures, or the thickness of the sheets, may be reckoned by inches, by feet, or by hundreds of feet, according to the varying texture of the rock-masses involved, or the different dynamic conditions which have produced the fracture.

It will at once suggest itself that these are all phenomena characteristic of faults. But they are also found, at times, where there may be no recognisable evidence of actual displacement of the rock-masses on either side of the fissure or fracture. On the other hand, it will be equally evident that fissures characterised by these phenomena can hardly be the result of contraction, or shrinkage-cracks.

Striations are not confined to well-defined fissures, but are found on smaller planes within rock-masses; but in any case they seem to necessarily give evidence of movement under pressure, be the amount of that movement ever so small.

Fragments of country-rock are often rounded. These have less probably fallen into the fissures from the walls, and become rounded by attrition either against the walls or against each other, than been produced by the rubbing or dragging of one wall against the other. The greater or lesser size of the fragments would, in a measure, prove a greater or less distance between the walls, but it seems that under the enormous pressure that must have accom-

Fractures—continued.

panied these rock-fractures, the space between the walls must have been more or less completely filled with attrition material, only part of which would be actual rock-fragments, and the rest finely comminuted material, which, under the dissolving agency of percolating waters, would finally result in more or less impure clays. The rounding of the fragments, on the other hand, is readily accounted for as the action of these same percolating waters, it being a well-recognised fact that the decomposing action of moisture in any form acts more rapidly on the corners or angles of a rock-mass than on its flat surfaces, and the sharper the corner the more rapidly is it eaten away.

Crushed zones are merely larger phases of the same actions as produce the breccia-material, and are subject to the same general laws, only differing in their greater dimensions and the more irregular shape of the enclosing walls.

The sheeting of the country-rock in faulted or fractured regions where ore-deposits abound is a phenomenon to which hitherto too little attention has been paid. Its importance as a feature of fissure-veins is, however, great both from a geological and from a practical point of view. That it has hitherto escaped due recognition is probably due to the prevalence of the old idea that vein-deposits are necessarily the filling of open fissures, and to the failure to appreciate to how great an extent they are actually the replacement of rock-material rendered more readily accessible and attackable by the dynamic movements which produced the fissure.

From individual fissure-faults there is a gradual transition into co-ordinated fractures, as a rule greater in number in a given area, but of less individual extent, which form a sort of fractured zone with two or more prominent directions of fracture, apparently of nearly contemporaneous formation. These Emmons calls *compression-joints*, because they always show one or more of the evidences of compression, viz. striation, brecciation or crushed material, and sheeting of the country-rock. Such complicated systems of fracture would appear to involve the action of more than one system of dynamic movement; that is, of forces of compression acting at the same time in different directions, and hence combining with the direct plicational strain more or less strain of torsion.

In the larger joints or fractures observed in mining districts, the effects of direct compression have been more marked, and the effects of the torsional strain are probably more seen in the minor fractures, or stringers and leaders, as the miners call them. In the map of a mining district characterised by a multitude of small veins, it will be found that the more detailed the map and the more thoroughly the veins have been explored and represented thereon, the more regularity and uniformity in their directions are shown. It must be borne in mind, however, that such a map never represents the totality of the fissures in the district, but only such parts of them as have been found sufficiently rich to exploit for ore.

Fractures—continued.

It is evident that by a succession of dynamic movements, especially when accompanied by torsional strains, an almost infinite variety of fissures and passages for mineral-bearing waters may be produced, and that it would therefore not be possible beforehand to describe all the various structural conditions under which ore-deposits may occur. But certain conditions suggest themselves as a result of the structural method of considering them that would seem to have a general application.

Structural Generalisations.—Extent of Fissures.—Since the dynamic movements are confined to the crust of the earth, it is evident that the fissures produced by them cannot literally have an indefinite extent in depth, though in certain cases it is very possible that this extent may be practically indefinite, as it may go beyond the limits at which mining is practicable. It is fair to assume that those fissures which have the greatest horizontal extent will have the greatest extent in depth; in other words, that their vertical and horizontal dimensions bear some sort of proportion to each other. If, therefore, as some have maintained, the vein-filling has in all cases been brought from some source at great depths in the earth, the greatest fault-fissures would be expected to be the greatest and most frequent ore-producers, since they would reach nearer to this unknown source.

But rather the reverse is the case, which, as far as it goes, furnishes an argument in favour of the view that the vein-material has been derived from the surrounding, though not of necessity absolutely contiguous, rocks. On the great fold-faults are found no considerable deposits of ore, and it is comparatively rare that continuous deposits are found along a single well-defined fault-fissure. The majority of deposits seem to occur where there are a series of fissures, more or less regularly co-ordinated, in which several of the series are prominently accentuated. In such systems there seems to be a tendency for the rich ore-bodies or bonanzas to extend in a direction which lies at an angle with that of the main fissure, or to continue for a certain distance along one fissure and then to pass into another fissure, set off at a little distance from the first. It would seem probable that there must be some structural reason for the concentration of ore in this way. The practical lesson to be learned is that the miner should not confine his explorations to the single fissure in which his ore occurs, but when he runs out of bonanza in that, he should seek a continuance of it in some adjoining fissure or plane, in a direction to be determined by the study of the system of the fracturing of the region and of the general direction of the bonanzas.

Vein-walls.—The second generalisation is in regard to the *walls*, which have generally been considered an important and almost indispensable characteristic of a true fissure-vein. The typical wall which the miner considers an evidence of a strong and well-defined fissure-vein is a comparatively smooth, generally striated,

Structural Generalisations—continued.
rock-plane, and frequently coated with a clay selvage—a band of decomposed argillaceous material which itself generally shows evidence of pressure and movement. From the above structural point of view of the origin of vein-fissures it is evident that the character of the wall and selvage is dependent on the composition of the rock and the amount of displacement and pressure. The grinding of one face of rock against another will undoubtedly tend to plane both off and to produce a certain amount of fine attrition-material; but this attrition-material will not necessarily be reduced to clay unless it has further been subjected to the decomposing action of water, which has carried off certain portions and left an argillaceous residue. The extreme instance of such decomposition is found in the muddy accumulations at the bottom of caves in limestone, which are simply the less soluble residues, mostly silica and alumina, resulting from the dissolution of large quantities of more or less impure limestone.

These walls and selvages are a frequent accompaniment, but by no means an essential characteristic, of an ore-bearing fissure. It is quite conceivable that one or both may be wanting; and such occurrences are not uncommon in nature. Take, for instance, the veins of Butte, Montana. These are a series of co-ordinated fractures or compression-fissures in a remarkably homogeneous mass of granite. Apparently there has been little or no displacement of the walls of these fissures relatively to each other; hence, but little attrition-material has been produced; and for this reason—and probably, also, on account of the character of the rock and because it was not much decomposed along the fissure-planes before the advent of the ore-bearing solutions—no clay selvages have been formed, and the ore-bearing solutions have eaten into the wall-rock to varying distances, replacing it more or less completely by vein-material, and leaving no definite boundaries or walls to the deposits. There is no reason, however, for considering them any the less true fissure-veins or less valuable ore-deposits on this account.

On the other hand, under certain conditions, instead of an absence of well-defined walls there may be so many as to mislead the miner who depends too implicitly upon them as a boundary of his ore-body. In the Gunnison region, for instance, where, owing to the plasticity of the country-rock, it has been divided along the main fracture-planes into a series of very thin parallel sheets, the space between these sheets has frequently been filled by quartz, which thus forms a thin sheet, often so completely reproducing the form of the fissure as to present a cast of the striation-surfaces. Such a sheet of quartz, when the adjoining bands of country-rock have been replaced by vein-material, forms a hard, well-defined wall to the ore-body, which delights the eye of the honest miner and enhances in his mind the value of his property.

Ore may be found as well on one side as on the other of such a wall, and not unfrequently is apparently confined to one side for a

Structural Generalisations—continued.

considerable extent along the length of the vein, and then is found almost as exclusively on the other side. In one prominent instance a new body of rich ore was struck by cross-cutting into the foot-wall country. The moral is that judicious cross-cutting forms a very important part of vein-mining, but should be conducted with due regard to the fracture-system of the adjoining country, and to the evidence to be obtained as to the course followed by the ore-bearing currents, or it may involve an unnecessary amount of dead work.

Banded structure.—In most of the deposits of the Gunnison region, there is a noteworthy appearance of banded structure parallel with the walls of the fissure. The evidence of faulting and of the thin sheeting of the country-rock is there so clear that the explanation at once presents itself that this appearance arises from the fact that the deposits are partly a filling-in of interstitial spaces, and partly a replacement of thin sheets of country-rock, the differing composition of the bands resulting rather from the necessary variation in the process of deposition than from essential differences in the ore-bearing solutions. Were one to examine there only a large body of rich ore, and neglect to examine the adjoining poorer deposits, and to study the structural conditions of the region, one might be led to adopt some of the complicated explanations set forth in books on ore-deposits, such as successive reopenings of the vein, to account for the conditions found, instead of the simple one given above.

Crushed zones.—Cases occur where the systems of rock-fracture intersect each other, and under suitable conditions considerable portions of the country-rock included between such intersecting fractures may be broken up or crushed to such an extent as to admit a relatively free passage of percolating waters. Where such waters are mineral-bearing, the interstices between the fragments will offer spaces for the precipitation of their contents, or where the rock is readily soluble the fragments themselves may be replaced by vein-material.

Where three or more nearly vertical fracture-planes intersect each other near the same point, the prismatic body of rock included between these intersections may be so crushed and broken as, in a district rich in mineral-bearing solutions, to give rise to what are generally known as chimney deposits. Where the fracture-planes are merely joints along which there has been but little movement, and no clay selvages have consequently been formed, the ore-solutions will eat out into the rock in such a way that the ore-chimney may appear to have a rounded instead of an angular horizontal section, and the fracture-planes themselves may have become, by the decomposition of the adjoining country-rock, so obscured as to be with difficulty traced in the immediate vicinity of the ore-body.

Repeated movements along fissure-planes.—It is a well-recognised

Structural Generalisations—continued.

fact of structural geology that in successive dynamic movements in the same region there will be a tendency for fractures to follow already determined planes of fracture. Furthermore, it appears that the faulting of a rock-mass is not necessarily a geologically instantaneous movement, but that the displacement may continue for some time after the first fracture has been determined, probably dying out very gradually. Some such continued movement seems necessary to give time for the reduction by the action of water of the attrition material to the clayey condition in which it is often found. We may expect, therefore, to find evidence in large fissures of repeated movements.

Cross-fractures, and even apparent displacement of one fracture by another, may be produced by one and the same strain. Hence, in studying a system of fissures, one must not too hastily conclude that each direction of fracture means a distinct movement, or even that displacement of one fissure by another necessarily proves that the latter was produced by a distinct and later movement; to be sure of this, some of the other evidences of movement must be found.

Some very interesting facts in connection with two adjacent properties in Boulder Co., Colorado, are worthy of notice. The vein A runs first in porphyry, then in contact between porphyry and granite, and sometimes wholly in granite. The vein stone is a hard flinty white quartz. The gold is free and often very coarse; rarely accompanied by pyrite and chalcopyrite, increasing on entering the granite, when blende and galena also occur, but as tellurium-minerals.

The vein B is a bluish quartz, with chalcedony and finely disseminated pyrites. The value is in metallic gold, petzite, and sylvanite. While most of the metallic gold was deposited as native gold, a certain portion has evidently been rendered free by the partial decomposition of the tellurium-minerals. The richest ore usually occurs in two narrow seams or streaks, often only 1 ft., but at times as much as 10 ft. apart; the intervening space is more or less mineralised country-rock. The miners working as lessees on this vein consider it richest in the schistose rock, and poorest when it is in the porphyry, on its course through the dyke. Though the openings on the vein, in the dyke, are limited, this opinion appears to be correct.

So distinct are the characteristics of these veins, that the crossing of B through A is plainly marked, and confirms the opinion that the gold-mines of the country belong to at least two distinct periods of vein-formation.

That the ores from B (the tellurium-vein) are of lower grade where the vein passes through the porphyry dyke than elsewhere may be due to the formation of the A vein first. This vein probably drained the dyke of much of its disseminated mineral values. B doubtless received its mineral through the schistose or gneissic

Structural Generalisations—continued.
rocks, and is consequently richer where enclosed in those rocks than in the dyke.

Prospectors, as a rule, look for richer or larger bodies of ore where veins unite or cross each other. In this property we have two interesting occurrences of this kind. The A veins unite at a point 100 ft. below the surface. These are similar veins of the same age. The result is seen in larger and richer ore-bodies mined in the stopes adjacent to the junction of the veins. In the other case, the crossing of the B (tellurium) vein through the A veins, which was the passing of a later through earlier veins, produced no local enlargement or enrichment of the ore-bodies. It may be inferred with probability as a general rule, subject of course to local exceptions, that for the production, by the junction of two veins, of ore-bodies larger or richer than are characteristic of either vein separately, the two veins should be of contemporaneous origin.

Perhaps this last proposition may be both confirmed and explained by restricting its application to such cases of enrichment as result from the simple enlargement of the space available for deposition, and the consequent diminution of the speed of percolating currents—both of which conditions are observed to produce similar effects in veins which vary in dip or width but are not intersected by other veins. Practical miners look for the larger ore-bodies in the flat places and the wide places of the vein; and the pinches, though they do now and then compensate by special richness for their contracted size, are usually as "lean" as they are thin.

The theory of the formation of ore-deposits by replacement, as opposed to that by the filling of pre-existing cavities, may be applied to deposits in rocks which are not so readily soluble as limestone, in which cases the percolating solutions would have first attacked the relatively more soluble among their constituents. Very many so-called fissure-veins in crystalline rocks are formed by percolating water circulating along joints, shrinkage-cracks, fault-planes, or zones of crushed rock, which have filled the interstitial spaces and replaced the materials of the adjoining country-rocks to a greater or lesser extent by the materials they held in solution, but are not the filling of any considerable open cavities. The comb-structure of veins, on which the early geologists founded their theory that a vein was necessarily the filling of a pre-existing open cavity, is of comparatively rare occurrence.

Cracks or fissures must undoubtedly have existed, which determined the concentration of mineral solution along their course; but whether such cracks were to any great extent fault-planes, whose movement might have left large open spaces between the irregularities of their walls, seems questionable. In Leadville one of the most noticeable facts is that the fault-planes, which may be supposed to reach to great depths, have been found barren of ore except by secondary infiltration from surface-waters, or as

Structural Generalisations—continued.
attrition-material from pre-existing deposits, when the fault-line cuts across such deposits.

The idea that a fissure vein necessarily extends to an indefinite depth is another popular error, and not founded on good geological reasoning. Whatever the nature of the fissure along which the deposit has taken place, whether fault-plane, joint, or shrinkage-crack, there must be some mutual relation between its horizontal and its vertical dimensions. In other words, the study of structural geology shows that the length of such a fissure or crack must bear some proportional relation to its extent in depth, and the probability is that the latter must be less than the former.

The present tendency of the results reached by careful and well-authenticated determinations of the origin and manner of formation of ore-deposits is in favour of a continually increasing applicability of the following conditions:—

That they are deposited from solutions made by percolating waters.

That the deposition takes place very rarely in actually open cavities, but most frequently by a metasomatic interchange, or by replacement of the more soluble or more accessible portions of a rock or members of a rock-series.

That these solutions do not necessarily come directly upward, but simply follow the easiest channels of approach.

That these materials are not immediately derived from sources at some unknown depth, but from neighbouring bodies of rock within limited and conceivable distances.

That where, as is so often the case, ore-deposits are associated with, or in the vicinity of, bodies of eruptive rock, especially the older intrusive rocks, there is a reasonable probability that their materials have been derived from these rocks.

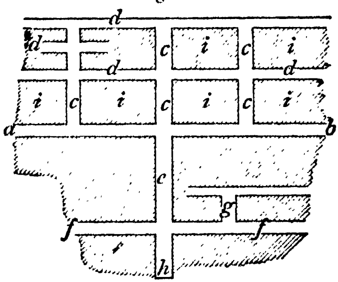
If the solutions came from the country-rock, at or above the level of the ore-deposit, it is most likely that the hanging-wall will be more or less obliterated, and the foot-wall relatively distinct. This follows from two considerations: first, because the rock of the hanging-wall is in such a case the main source of the water-supply for the fissure, the natural effect of gravity (apart from special water-channels) being to carry the waters of the foot-wall away from the vein, and to some other vein below it; and secondly, because the disintegrated rock of the hanging-wall would naturally deposit debris on the foot-wall, protecting it from disintegration, and thus preserving its definite form. The only "boundary" of such a vein would be a commercial one, viz. the line at which the ore ceased to pay.

MINING METHODS.

Veins.

(*a*) *Overhead mining when the vein does not exceed* 2 *fathoms thick.*—The main adit or level *a b*, Fig. 38, is first driven, and from this at intervals the winzes or shafts are made *upwards* as at *c*, and from these again other levels *d* are driven. Similar operations are

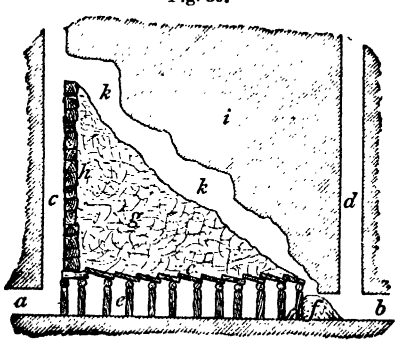
Fig. 38.



Overhead Mining.

extended downwards as at *e f g*, the bottom of the shaft *c* forming a sump at *h*, into which the mine water will drain and from which it must be pumped.

Fig. 39.



Overhead Mining.

The manner of excavating one of the square masses of ore *i* is better seen in Fig. 39, where *a b* is the adit; *c d*, shafts; *e*, timber-

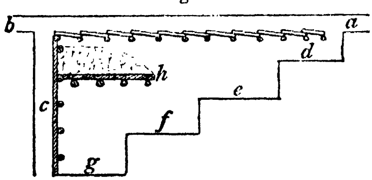
Veins—continued.

ing which forms the roof of the adit, and at the same time the floor of the chamber being excavated; *f*, a heap of ore broken down from overhead ready for running out of the adit; *g*, that portion of the mineral which has no value, and which accumulates under the feet of the miners as their work progresses; *h*, a substantial wall forming one side of the shaft *c*, sometimes built of the larger pieces of rock broken down from *i*, but more often timbered; *i*, the unworked portion of the vein; *k*, space in which the miners wield their tools.

The advantages of this system are that less timber is needed, and the ore is more easily brought to bank; its disadvantages are that the miner has to reach upwards to his work, and that some ore must necessarily get mixed with the rubbish *g* and be lost. It is by far the most widely adopted.

(*b*) *Underhand Mining when the vein does not exceed* 2 *fathoms thick.*—From the main adit *a b*, Fig. 40, a shaft *c* is sunk on the vein.

Fig. 40.



Underhand Mining.

Then, commencing at *d*, miners standing on the ore in the vein excavate it in a series of steps *d e f g*, the ore having to be raised by windlass or other contrivance through openings in the floor timbers of the adit *a b*, whilst the rubbish is thrown back on strong timber shelves *b* built against the wall of the shaft *c*.

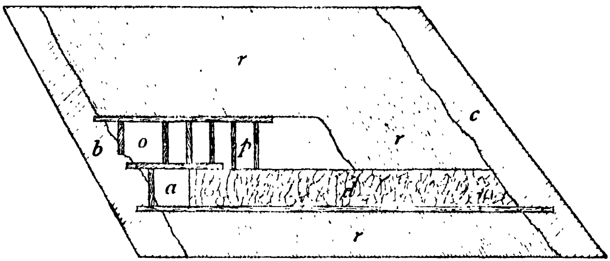
The advantages of this system are that the miner has easier access to the ore, and can apply more power, whilst the loss of ore is less. The disadvantages are extra cost for timbering and transporting ore to bank, and increasing difficulties in ventilation and removal of water.

(*c*) *Crosswork on veins over* 2 *fathoms thick.*—With very thick veins it is necessary to modify either of the systems before mentioned, so as to deal with the width of the vein in successive sections. This is illustrated in Figs. 41, 42. A main gangway *a* is first driven along either wall *b c* of the vein *r*, and substantially timbered. From it a series of breasts or crosscuts *d e f g h i* are driven at right angles through the vein till they reach the opposite wall *c*. These breasts are 1 fathom high and 1–2 fathoms wide, and are so worked as always to have firm ground on both sides of them, either solid ore as at *k l m n*, or rubbish stowed back in a former breast as at *d*.

Veins—continued.

As one level is worked out, new gangways, as at *o*, are driven overhead, and the crosscutting is repeated, with timbering *p* where necessary, and always providing that no two breasts in the same vertical line shall be worked simultaneously.

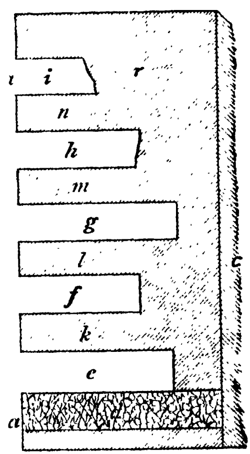
Fig. 41.



Crosswork on Thick Veins.

(*d*) **A modification of the ordinary method of timbering in mines, which has long been in general use on the Pacific Coast, is shown**

Fig. 42.



Crosswork on Thick Veins.

in Figs. 43, 44. Sawn timber is used throughout, the uprights and cross-pieces are 10 in. × 10 in., and stand 4 ft. 6 in. apart;

Veins—continued.

along the course of the drive, the cross-pieces are 5 ft. long, and the height of the main drives and sill floor sets is 7 ft. 2 in. clear.

Fig. 43.

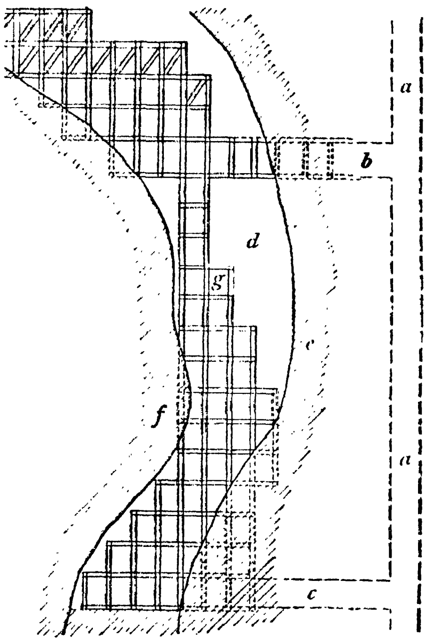
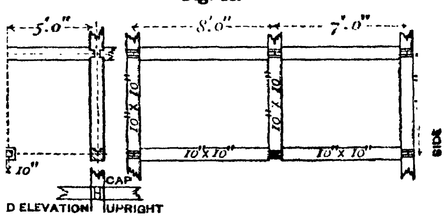


Fig. 44.



Square or Nevada Timbering.

In blocking out the stopes, the uprights are 6 ft. 2 in., just 1 ft. shorter than those in the main drives. The caps and struts are of

Veins—continued.
the same dimensions and timber as the sill floor. The planks used as staging are 9 in. × $2\frac{1}{2}$ in.; they are moved from place to place as required, and upon them the men stand when working in the stopes and in the faces. A stope resembles a huge chamber fitted with scaffolding from floor to roof. The atmosphere is cool and pure, and there is no dust. Stage is added to stage, according as the stoping requires it, and ladders lead from one floor to the other; the accessibility to the faces is a great advantage. If, whilst driving, a patch of low-grade ore is met with, it can be enriched by taking a higher class from another face, and so on; any grade can be produced by means of this power of selection. Opinions have been expressed that this system of timbering is not secure, and that pressure from above would bring the whole structure down in ruins. But if signs of weakening in the timbers become apparent, the remedy is very simple. Four or more of the uprights are lined with planks, and waste material is shot in from above, and a strong support is at once formed; or if signs of crushing are noticed, it is possible to go into the stope, break down ore, and at once relieve the weight. The cost is said to be 30 per cent. less than in the usual system, the ventilation is unimpeded, and much timber is saved. This method is commonly known as the "Nevada" or "Square" system of timbering.

(*e*) Excellent examples of the contingencies arising in the course of long continued mining operations are afforded by the East and West Vulcan mines of the Penn Iron Mining Company, Michigan. The ore occurs here in immense bodies, lying between hard jasper-slates and soft clay slates; it is soft hematite, and varies in thickness from a few inches to over 100 ft. The earliest mining methods were of the crudest sort, but the gradual increase of depth and multiplication of difficulties have compelled successive improvements.

The first was the introduction of the Nevada system of timbering, which, as already described under (*d*), p. 278, consists in filling the space exhausted in the ore-body with a series of frame cubes. These cubes are constructed with white pine timber of excellent quality, 12 to 15 in. sq., framed into squares of 7 ft. from centre to centre. There is great value in this system of timbering as related to strength, facility in erecting, and its adaptability to all thicknesses of ore-deposits or variations in hanging and foot-walls. When the walls are tolerably firm and not easily softened by exposure to the moist atmosphere of the mine, it possesses great strength; but where the hanging-wall is of soft clay-slates, softening rapidly on exposure, this system with its large timbers affords only temporary support. When the crush begins, the upright posts lose their vertical position, and many of the timbers are reduced to splinters. Collars and cross-braces are sometimes used to arrest a squeeze; but a brief respite only is secured in this way. The flexure of a soft hanging-wall indicates the early crushing of timbers in the

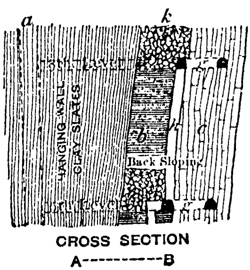
Veins—continued.

exhausted portion of the level. It becomes then a struggle on the part of the miner to remove as much as possible of the ore out of the creeping level before the final crush comes to close out all mining operations. It has thus been found that for certain qualities of mine-walls this elaborate system of timbering fulfils its office satisfactorily, but that under a softening hanging- or foot-wall it is not reliable for a sufficient time to afford opportunity for exhaustive mining in each level, or to protect ways to the adjoining level. The depth to which it can be safely carried depends on the firmness of the hanging- and foot-walls more than on the increased pressure from depth, although the latter is also an important factor.

The latest and modern method of "rock-filling" was compelled by the conditions, already described, in the West Vulcan mine. At the eighth level the ore is 600 ft. long and the average thickness about 25 ft. The shaft is 665 ft. deep to the ninth level. The timbering, mainly after the Nevada system, has been carried to the eighth level. Rock-filling is now being used in the ninth level.

Figs. 45–47, show the method of this filling. From the main shaft *a* a drift cuts the ore-body *b* and 25 ft. into the foot-wall *c* of

Fig. 46.



Rock-filling at West Vulcan.

firm jasper-slates. From this point *d* a rock-tunnel *e* is driven in the foot-wall *c* east to shaft *f*. Along this rock-tunnel *e* ports *g* are made at intervals of about 100 ft. into the ore-body *b*. From these ports the mining of the ore begins on the bottom of the ninth level.

The first cut of this ore is mined about 8–10 ft. high, and the spaces from which the ore has been removed are filled with rock. This rock-filling *k* follows the mining and affords absolute safety and inflexible support to the walls of the mine. The broken rock for filling is conveyed down the winzes *h*, and the ore through the shutes *i*, which are built up as fast as the filling is made upwards.

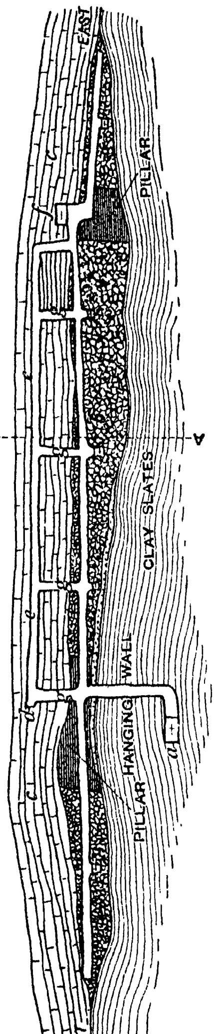


Fig. 45.

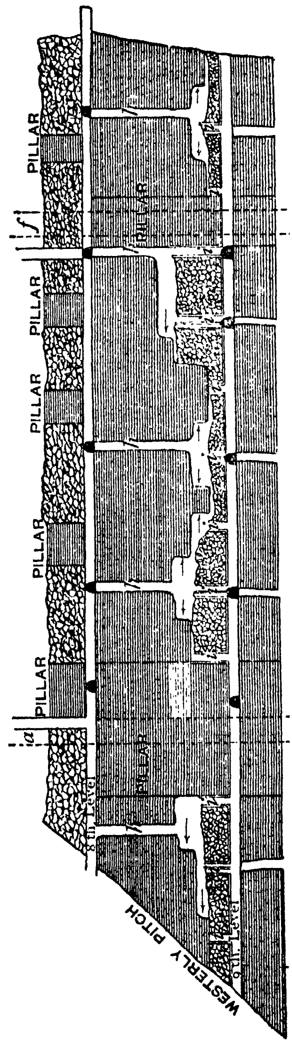


Fig. 47.

Rock-filling at West Vulcan.

Veins—continued.

It will thus be seen that the tunnel *e* in the foot-wall secures absolute safety to the mainways of each level; it is out of the crush range in any event. The winzes *h* are also ventilators, and greatly improve the sanitary conditions of the mine.

The ore-body *b* is under this system attacked by the miners on double face at each port *g*, from the main rock level or tunnel *e* in the foot-wall. The mining by sections upwards is simply a repetition of the first 8–10 ft., the rock filling following the mining work and occupying the spaces from which the ore has been removed as rapidly as room for the mining operations will permit. Some timbering will be required occasionally in this rock-filling, especially in sustaining the filling in upper levels, as it is approached from below in removing the last cut of ore.

This rock-filling system has not been adopted on the score of economy over the Nevada system of timbering, but has been compelled by the necessities of the case. Sufficient work has not been done to afford a reliable statement of the relative cost of the two systems. Nor would such a statement at any time form a permanent basis of comparison, because the forests of this region are being exhausted, with consequent effects on the market prices of timber, while the cost of breaking up and shooting waste rock into the mine fluctuates but little. The price paid for timber and timbering at West Vulcan in 1887 was 1*s*. 7½*d*. per ton of ore mined. The cost of rock-filling, with attendant consumption of timber per ton of ore mined, was 7*d*. a ton for rock-filling and 3*d*. a ton for timber used therewith. These estimates require verification by a few years of actual work. It may be pointed out that the rock-filling affords a permanent support, which is not liable to decay as is the timbering system, and will not require renewals during the progress of the mine-workings.

There are other important factors in connection with the general application of this system of rock-filling, e. g. the location of the shafts or slopes to the mines. The first planning of these slopes or skip-ways placed them in the ore-body, requiring large pillars of ore for their maintenance. Where the ore is of moderate thickness (12–15 ft.) this method is not so open to criticism; but when the ore-body is 20–100 ft. thick and rather soft, it has serious drawbacks in the great pillars of ore which must be set apart for this purpose, and in their tendency to crumble, especially in the event of a creep or crush, which follows in a greater or less degree in exhaustive mining. The use of skip-ways in the foot-walls, or the sinking of shafts in the hanging-walls, are matters of the greatest importance in assuring safe and economical mining. It has been shown that slopes or skip-ways in the ore-body are open to serious objections in large deposits of ore. It is quite possible to sink the slopes or skip-ways in the foot-wall, especially when this is firm. They could be driven in the foot-wall, and a sufficient distance under the plane of the ore, say 10–20 ft., so as to assure a perma-

Veins—continued.

nent rock tunnel under all conditions of creep or crush. This will have some exceptions, as where the ore-body is much flexed and pitching; but there are many deposits where a slope or skip-way could be driven in the foot-wall of an ore-deposit, and be readily made to conform to the flexures met, in ordinary cases, in these foot-walls. This would be costly at first, but it would ultimately be found to assure great safety, and permit exhaustive mining, since no pillars would be required for its protection.

West Vulcan mine exhibits an example of approaches by slope or skip-ways, partly in foot-wall slates, and a vertical shaft in the soft slates of the hanging-wall. The location of the main shaft in the hanging-wall was the result of several conditions bearing on the ultimate economy of mining its ore. It is near the siding of the railroad, affording a ready way for delivering the ore into railroad cars, and also for receiving coal by the same way for the boilers, and timber for the mine. This location also reduced largely the height of the pumping column, and the shaft was sunk in soft slates rapidly and cheaply. Aside from these special conditions, the locating of a shaft in the hanging-wall cannot be commended, as there is generally some shifting in the hanging-wall ground, endangering shaft and machinery.

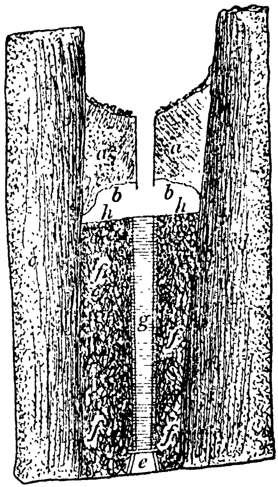
It has been a matter of discussion whether the usual method of mining by beginning operations at or near the surface and working downwards, in the best plan. It is true that it affords a ready output of ore, and a quick return of money; but, unless permanent rock-ways are established, it involves increasing expenditure in the downward workings. It is submitted, that in deposits of ore of moderate thickness, a slope could be cut in the ore to the bottom of the deposit, and workings commenced there, entirely exhausting the ore in the progress of the working upwards. The exhausted spaces below would afford a ready place for mining refuse, and could, if necessary, be supplemented with additional rock-filling. Even should the hanging-wall swell or buckle, no serious injury could result, as such a crush would be arrested at each level. (J. Fulton.)

The objections to the rock-filling system are the amount of dead work entailed, and the inconveniences and destruction of timbering owing to the ground sinking unevenly under foot.

(*f*) The system of mining in use at the Iron River mine, Menominee region, is extremely well adapted to ores hard enough to stand over the width of the vein. A section across a stope (Fig. 48) shows the method of work. The ore *a* is taken down in an overhand stope *b* running the width of the vein from the hanging-wall *c* to the foot-wall *d* for any desirable length, and for a height of say 12 ft. A timber-drift *e* is then built along the floor of the stope, and the balance *f* of the stope is packed with waste sent down from the surface through winzes previously sunk or upraised at intervals of about 50 ft. in the length of the stope. A "mill" or "chute" *g*

Veins—continued.
is carried up every 50 ft. along the level to run the ore down; it is about 4 ft. sq. inside, and is built of round, rough hardwood sticks. The spaces between the sticks when they do not fit closely are filled with pieces of plank, and the inside of the "mill" is lined with hardwood planks spiked on to the side timbers. These planks are easily replaced when worn. The packing is levelled over as close to the backs of the stope as is convenient for working, and is planked *h* over, to keep the ore from mixing with the filling. The "mill" is

Fig. 48.



Working on Hard Vein at Iron River.

carried up before the filling as high as this is to go; and when the filling is levelled off, a few large sticks are laid across the mill, leaving intervals large enough to throw the ore down, but so narrow as to prevent the falling in of a man or a block of ore that would choke up the outlet from the mill. This method is extremely satisfactory where the ore is strong enough to stand without timbering across the vein. It requires no timber, except for the level and the mills, and a few planks, while permitting the extraction of nearly all the ore. The cost of filling at Iron River was only 6½*d.* a ton on the ore got out, but on the average this figure would be much exceeded.

(*g*) For working in large soft ore bodies, Rothwell thinks it would be found in every way advantageous to work the vein out from the top downwards. He would drive the main levels *a* in

Veins—continued.
the vein *b* (Figs. 49–50), and most conveniently on the footwall *c*, *d* being the hanging-wall. As the ground is undisturbed, it should be feasible to keep open a level the width of an 8-ft. set, no matter how soft the ore, thus avoiding much dead work. At suitable

Fig. 49.

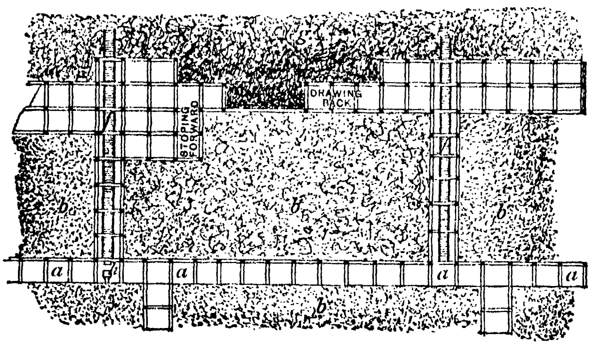
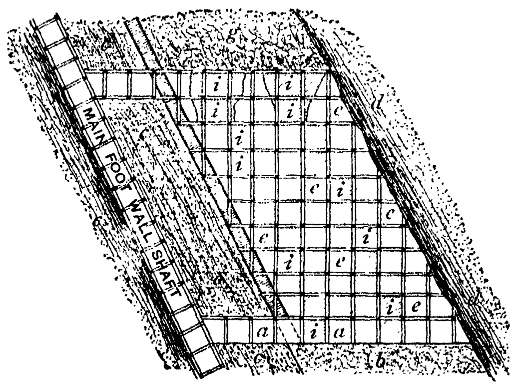


Fig. 50.



Working Downwards on Soft Ore Bodies.

intervals the vein would be cross-cut *e*, and stoped out the width of one set, up from one level to the next above. However soft the ore it should be possible, even with rather light timber, to hold a stope only 8-9 ft. wide running across the vein in the solid well-

Veins—continued.
drained ore. This will take the place of winzes and cross-drifts at much less cost, and will serve as a pocket or chute *f* to hold the ore, which can be drawn thence into the cars *h* below; or the mill or chute *f*, through which the ore is sent down, can be built say 3½ by 4 ft. in the clear, of round hardwood sticks lined with hardwood plank. By a little care in packing round it, this can probably be held in the filling *g* as a waste mill, through which filling may be sent down from above; or the mill can be cut in the foot-wall. When the cross-stope reaches the upper worked-out ground, longitudinal stopes *i*, one or two sets in height and one set in width, are driven to half the distance between the cross-stopes, leaving between them intervals or pillars two sets wide or more if the ground permits. These longitudinal stopes are timbered lightly, having to stand but a very short time, and being in the solid undisturbed ore, with the filling from above resting on each side of them on solid ore. When the mid-distance between the cross-stopes is reached the back-stoping commences by taking out the ore on each side of the stope *i* to the width of a set, or half the pillar left between the longitudinal stopes *i* supporting the "gob" roof while doing so, and laying lagging poles or slabs across the floor of the stope as the work proceeds. Any waste rock or material available or desirable may be thrown back in the packing, and when a space the area of one or two sets is worked out on each side of the last sets of the longitudinal stope *i*, the temporary timbering is drawn, and the "gob" roof, with the lagging previously laid under it, is allowed to drop on the bottom of the stope lagged to receive it. Light poles, and even brushwood, will serve for thus keeping the ore from mixing with the waste. It will probably be found possible, as well as advantageous in many cases, to drive these longitudinal stopes *i* two sets high, and draw back the upper one a little in advance of the lower, and as they can be driven out at any point in the cross-stope, a whole horizontal slice or section of the ore-body, no matter what its thickness, can be opened out, say two sets in height, at the same time.

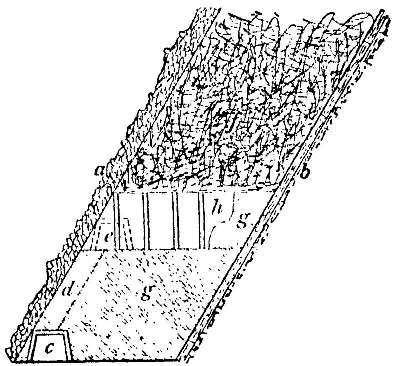
The advantages claimed for this system are: (1) that all the work is simply stoping; (2) all levels and stopes that have to be timbered are in solid, undisturbed ore, and being only one "set" in width, are easily held, and require but light timber, while much of this is drawn and saved in letting the roof down; when the stope comes up to the filling, this has only to be supported over one set of timber, while it rests on the solid ore on each side; (3) the filling follows the ore down, and as long as this occurs, the cave on the surface can be constantly filled from "borrow pits" much cheaper than by sending the filling below; (4) it is possible to obtain practically all the ore in the vein, and to get it free from mixture with waste; (5) caves or crushes are impossible; (6) more ore can be extracted from a given amount of ground in a given time.

(*h*) Another example of working in soft ore bodies is that at

Veins—continued.

Low Moor, Virginia. The ore is generally soft, and all drifts require close timbering. The hanging-wall *a* (Fig. 51) is a band of broken flint and clay, and the footwall *b* is sandstone. Main levels *c* are driven in the vein along its strike, 60–80 ft. apart vertically, starting from the surface on the side of the hill or from a hoisting shaft in the valley.

They are usually on the flint wall, whether it be the foot or the hanging, because the flint is a better guide in following the vein. These levels are driven along the vein to such a distance from the hoisting-shaft as may be required to reach all the ore which it is intended to raise through that shaft—in some instances over half a



Working on Soft Ore Bodies.

mile. While the main levels are being driven, the pillar between two levels is usually left untouched, except by up-raises connecting the two levels every 400–600 ft. for ventilation. When the levels are completed, the portions of two levels farthest from the hoisting-shafts are connected with up-raises *d*, 60–75 ft. apart, two or three up-raises are joined by air-drifts *e*, and the ground is ready for stoping. The timber in the air-drifts is recovered in stoping. The stopes are 12–15 ft. high, each pillar between two main levels making 4–6 stopes. As soon as a stope is worked out for 40–60 ft. along the vein, a floor is laid, consisting of sills covered with refuse timber or slabs, and the props are shot down. The waste material *f* from above packs solidly upon this floor, and in a short time the next lower stope can be worked, using the floor previously laid as a roof to hold the waste material from the ore. A stope 40–60 ft. long, measured along the vein, is begun in the drifts, by first mining the ore *g* above the drift-timbers till the floor of the next

Veins—continued.
stope above is reached, and setting props. The face of the ore for the length of the stope is then mined back to the opposite wall, as shown at *h*. The ore is dumped into the chutes *d*, drawn from them into cars on the main levels *c*, and hauled by mules to the surface or to the hoisting-shaft.

When the vein is 12 ft. or less in thickness, so that a single prop will reach from wall to wall, the method is somewhat modified. A stope-drift is driven a short distance above the main level, parallel with it, and connected with it by chutes at intervals of about 50 ft. The ore is then stoped from this drift to the next upper main level, props being placed from wall to wall. These props are eventually shot down, and the waste material is caught by a horizontal floor, which will serve as a roof for the next lower stope, as before. In this way the timber for a number of floors is saved, but the modification is only of advantage when the vein is narrow enough to permit a single prop to reach from wall to wall, and where, moreover, the hanging wall is fairly good. In this way all the ore is mined, no filling is required, and the work is comparatively safe. In some instances, means must be taken to exclude surface water from the breaks which run up to daylight when the country rock sinks to fill cavities.

(*i*) *Stripping.*—This term is applied to what is really simple quarrying adapted to the exploitation of a vein. It has been rendered possible by modern improvements in mining machinery and appliances, which allow of much more complete preliminary determination of the quality and extent of underground deposits, and much less costly blasting operations. The advantages of stripping are that the work is conducted in the open day, and that there is less risk of unremunerative dead work on the one hand and of overlooking ore on the other.

At the Peters mine, Ringwood, New Jersey, where the limit of profitable mining by the old method has been reached, it is intended to remove the ore floors and pillars by stripping. While the vein stands nearly vertical, the ore shoots overlie each other at an angle of 35° and some 10–30 ft. apart. It is proposed to take advantage of this, and pile up the waste on the end wall of the lowest shoot as rapidly as the wall is uncovered by removal of ore. This back filling will make the mine safer, and will save much excavation by allowing the slopes to be considerably steeper than if the pit were to be left open permanently.

At the Bertha zinc mines, in Virginia, zinc carbonates are found to the extent of about 8000 tons per acre, underlying some 80 ft. of earth, so that 30 cub. yd. of earth have to be removed for every ton of ore mined.

In the case of the Dannemora mine, Sweden, stripping has been successfully carried to a depth of about 500 ft., and at the Fahlun copper mines to even greater depths.

Beds.

(*a*) *Longwall.*—The "longwall" method, which closely resembles the overhead system already described, is applicable to nearly horizontal thin beds which furnish sufficient waste for filling. The

Fig. 52.

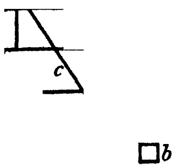
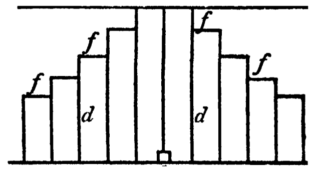


Fig. 53.



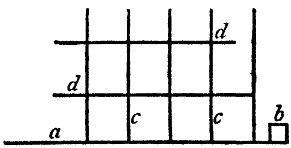
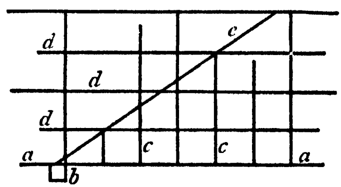


Fig. 55.



Longwall and Pillar and Stall Working.

main tunnel *a*, Figs. 52, 53, is built high enough to accommodate the trucks for transporting the mineral to the hoisting shaft *b*, and is run at the lowest part of the bed so as to form a natural drainage for the mine water. From it drifts are run into the mineral, either diagonally as at *c*, or transversely as at *d*, and connected by parallel levels *e*. The direction of the drifts is governed by the rate of dip of the bed, the object being to secure a suitable incline for the trucks which carry out the mineral. The workings are connected all round by cross-cuts as at *f*, to complete the circulation of air for ventilation.

(*b*) *Pillar and Stall.*—This system is adopted where the beds are thicker and do not afford sufficient waste for filling, so that pillars of mineral have to be left standing as a support for the roof. The main tunnel *a*, Figs. 54, 55, is run as before from the shaft *b*, and from it are run drifts *c* at intervals, and crossing these again, levels *d* parallel with *a*, and occasionally diagonal drifts *e*. The bed is thus divided into regular blocks, portions of which, varying in size, are left to form the pillars that support the roof, these being finally withdrawn as far as safety will allow.

Beds—continued.

In seams having a rate of dip of 40–60° it is the custom to drive the stalls square off from the gangway, up the "rise" of the seam, and have the coal to run down the shute into the tram at the bottom of it; with this rate of dip the shute does not require planking at the side or bottom to make the coal run, and by keeping the shute full, except 3–4 ft. working room at the breast, there is very little coal lost by pulverising in its descent down the shute, as by that method it descends by slow settling in proportion as it is allowed to run into the trams at the bottom.

In seams of 30–40° rate of dip, the miners are compelled to plank the sides of the shute to some extent, in order to enable the coal to slide down without assistance. In seams of 25–30° the coal will not descend in the shute unless the sides are partly planked, and the bottom covered with sheet iron. In working seams having a dip of 10° or under, the stalls are driven diagonally to the direction of the gangway, unless the rate of dip is less than 4°.

The trams or mine cars used in Europe are, in nearly every case, smaller than the American; the reason for making them so, in most cases, is an effort to reduce the enormous first cost of the deep shafts, by having a small shaft area, thus leaving but a small space for the mine cars or cages and pumpway; the small mine cars also suit the large number of boys employed in European mines.

COAL SEAMS.

Calculating Contents.

A rough and ready way of calculating the available contents of coal in a given area of seam is to take a basis of 1 acre 1 in. thick = 100 tons. A more correct way is to ascertain the sp. gr. and multiply by that. In round figures, the sp. gr. taken to two places of decimals will represent the weight of 1 acre 1 in. thick if the decimal point be struck out; thus sp. gr. 1·10 = about 110 tons per acre 1 in. thick.

Table 131.—*Coal Seams.* Sp. gr.; weight per acre, per cub. ft., per cub. yd., and per cub. ft. when broken.

Sp. gr.	Natural Weight per acre 1 in. thick.	Natural Weight per cub. ft.	Natural Weight per cub. yd.	Broken Weight per cub. ft.	
				Large.	Small.
	tons	lb.	tons	lb.	lb.
1·10	111½	68¾	·829	42½	37
1·15	116½	72	·867	44½	38¾
1·20	121½	75	·904	46½	40½
1·25	126½	78	·941	48½	42
1·30	131½	81¼	·978	50⅓	43¾
1·35	136¾	84¼	1·016	52⅓	45½
1·40	141¾	87½	1·054	54⅓	47¼
1·45	146¾	90½	1·091	56	49
1·50	152	93¾	1·129	58	50¼
1·55	156⅜	96¾	1·167	60	52¼
1·60	162	100	1·200	62	54

Coal Heaps.—To estimate contents of coal heaps, measure the cubic space occupied and multiply the result, stated in cub. yd., by 6; the product = contents in tons.

Table 132.—*Weight of Coal under* 1 *acre of land*, at 19 cwt. per cub. yd., or 78¾ lb. per cub. ft., approximate, and assuming seam to be level.

ft.	in.	tons.	ft.	in.	tons.	ft.	in.	tons.
0	1	127	3	5	5,212	6	9	10,260
0	2	254	3	6	5,346	6	10	10,390
0	3	381	3	7	5,468	6	11	10,520
0	4	508	3	8	5,596	7	0	10,650
0	5	635	3	9	5,724	7	1	10,780
0	6	762	3	10	5,852	7	2	10,910
0	7	889	3	11	5,980	7	3	11,040
0	8	1,016	4	0	6,096	7	4	11,170
0	9	1,143	4	1	6,124	7	5	11,300
0	10	1,270	4	2	6,252	7	6	11,430
0	11	1,397	4	3	6,380	7	7	11,560
1	0	1,524	4	4	6,508	7	8	11,690
1	1	1,651	4	5	6,636	7	9	11,820
1	2	1,778	4	6	6,764	7	10	11,950
1	3	1,905	4	7	6,892	7	11	12,080
1	4	2,032	4	8	7,020	8	0	12,210
1	5	2,159	4	9	7,148	8	1	12,340
1	6	2,296	4	10	7,276	8	2	12,470
1	7	2,417	4	11	7,404	8	3	12,600
1	8	2,534	5	0	7,532	8	4	12,730
1	9	2,661	5	1	7,660	8	5	12,860
1	10	2,790	5	2	7,788	8	6	12,990
1	11	2,917	5	3	7,916	8	7	13,120
2	0	3,048	5	4	8,046	8	8	13,250
2	1	3,176	5	5	8,180	8	9	13,380
2	2	3,304	5	6	8,310	8	10	13,510
2	3	3,432	5	7	8,440	8	11	13,640
2	4	3,560	5	8	8,570	9	0	13,770
2	5	3,687	5	9	8,700	9	1	13,900
2	6	3,815	5	10	8,830	9	2	14,030
2	7	3,943	5	11	8,960	9	3	14,160
2	8	4,070	6	0	9,090	9	4	14,290
2	9	4,198	6	1	9,220	9	5	14,420
2	10	4,326	6	2	9,350	9	6	14,550
2	11	4,454	6	3	9,480	9	7	14,680
3	0	4,576	6	4	9,610	9	8	14,810
3	1	4,700	6	5	9,740	9	9	14,940
3	2	4,828	6	6	9,870	9	10	15,070
3	3	4,956	6	7	10,000	9	11	15,200
3	4	5,084	6	8	10,130	10	0	15,330

Table 133.—*Area of Coal Seams when inclined.*

Amount of Dip.			Coal Contents.	Amount of Dip.			Coal Contents.
1 in	deg.	in. per yd.	sq. yd. per acre.	1 in	deg.	in. per yd.	sq. yd. per acre.
57¼	1	½	4,841	1·66	31	21½	5,646½
28½	2	1¼	4,843	1·60	32	22½	5,707¼
19	3	1¾	4,846½	1·54	33	23¼	5,771
14¼	4	2½	4,852	1·48	34	24¼	5,838
11½	5	3	4,858½	1·42	35	25¼	5,908½
9½	6	3¾	4,866½	1·37	36	26	5,982½
8	7	4½	4,876	1·32	37	27	6,060¼
7	8	5	4,887½	1·28	38	28	6,142
6¼	9	5¾	4,900	1·23	39	29	6,228
5½	10	6½	4,914½	1·19	40	30¼	6,318¼
5	11	7	4,930½	1·15	41	31¼	6,413
4¾	12	7½	4,948	1·11	42	32½	6,513
4¼	13	8¼	4,967	1·07	43	33½	6,618
4	14	9	4,988	1·03	44	34¾	6,728¼
3¾	15	9½	5,011	1·00	45	36	6,844¾
3½	16	10¼	5,035	·96	46	37¼	6,967½
3¼	17	11	5,061	·93	47	38½	7,096¾
3 1/12	18	11¾	5,089	·90	48	40	7,233¼
2·90	19	12¼	5,119	·87	49	41½	7,377¼
2·74	20	13	5,151	·84	50	43	7,529½
2·60	21	13¾	5,184	·81	51	44½	7,691
2·47	22	14½	5,220	·77	52	46	7,861¼
2·35	23	15¼	5,258	·73	53	47¾	8,040
2·24	24	16	5,298	·70	54	49½	8,217½
2·14	25	16¾	5,340	·67	55	51½	8,419¾
2·05	26	17½	5,385	·65	56	53¼	8,639¼
1·96	27	18¼	5,432	·63	57	55½	8,873
1·88	28	19	5,481½	·62	58	57½	9,139
1·80	29	20	5,534	·60	59	60	9,430
1·73	30	20¾	5,589	.58	60	62¼	9,759

The cubic contents in yd. may be deduced from this table by multiplying the figure in the fourth column by the thickness in yd. or fractions of a yd.

Ex. 1. A seam 1 ft. 6 in. thick lying at an inclination of 16¾ in. per yd. will contain 5340 sq. yd. × ·5 yd. = 2670 cub. yd.

Ex. 2. A seam 1 fathom thick lying at 39° will contain 6228 sq. yd. × 2 yd. = 12456 cub. yd.

MINERALS.

HARDNESS. (Dana.)

The comparative hardness of minerals is easily ascertained, and should be the first character attended to by the student in examining a specimen. It is only necessary to draw a file across the specimen, or to make trials of scratching one with another. As standards of comparison the following minerals have been selected, increasing gradually in hardness from talc, which is very soft and easily cut with a knife, to the diamond. This table, called the scale of hardness, is as follows:—

1, talc, common foliated variety; 2, rock salt; 3, calcite, transparent variety; 4, fluorite, crystallised variety; 5, apatite, transparent crystal; 6, orthoclase, cleavable variety; 7, quartz, transparent variety; 8, topaz, transparent crystal; 9, sapphire, cleavable variety; 10, diamond.

If, on drawing a file across a mineral, it is impressed as easily as fluorite, the hardness is said to be 4; if as easily as orthoclase, the hardness is said to be 6; if more easily than orthoclase, but with more difficulty than apatite, its hardness is described as 5½ or 5·5.

The file should be run across the mineral three or four times, and care should be taken to make the trial on angles equally blunt, and on parts of the specimen not altered by exposure. Trials should also be made by scratching the specimen under examination with the minerals in the above scale, since sometimes, owing to a loose aggregation of particles, the file wears down the specimen rapidly, although the particles are very hard.

In crystals the hardness is sometimes appreciably different in degree in the direction of different axes. In crystals of mica the hardness is less on the basal plane of the prism, that is, on the cleavage surface, than it is on the sides of the prism. On the contrary, the termination of a crystal of cyanite is harder than the lateral planes. The degree of hardness in different directions may be obtained with great accuracy by means of an instrument called a sclerometer.

TENACITY. (Dana.)

The following rather indefinite terms are used with reference to the qualities of tenacity, malleability, and flexibility in minerals:—

1. *Brittle.*—When a mineral breaks easily, or when parts of the mineral separate in powder on attempting to cut it.

Tenacity—continued.

2. *Malleable.*—When slices may be cut off, and these slices will flatten out under the hammer, as in native gold, silver, copper.

3. *Sectile.*—When thin slices may be cut off with a knife. All malleable minerals are sectile. Argentite and cerargyrite are examples of sectile ores of silver. The former cuts nearly like lead, and the latter nearly like wax, which it resembles. Minerals are imperfectly sectile when the pieces cut off pulverise easily under a hammer, or barely hold together, as selenite.

4. *Flexible.*—When the mineral will bend, and remain bent after the bending force is removed. Example, talc.

5. *Elastic.*—When, after being bent, it will spring back to its original position. Example, mica.

A liquid is said to be *viscous* when on pouring it the drops lengthen and appear ropy.

DIAPHANEITY. (Dana.)

Diaphaneity is the property which many objects possess of transmitting light; or, in other words, of permitting more or less light to pass through them. This property is often called transparency, but transparency is properly one of the degrees of diaphaneity. The following terms are used to express the different degrees of this property :—

Transparent—when the outlines of objects, viewed through the mineral, are distinct. Example, glass, crystals of quartz.

Subtransparent, or *semitransparent*—when objects are seen but their outlines are indistinct.

Translucent—when light is transmitted, but objects are not seen. Loaf-sugar is a good example; also Carrara marble.

Subtranslucent—when merely the edges transmit light faintly.

When no light is transmitted the mineral is described as *opaque*.

LUSTRE. (Dana.)

The lustre of minerals depends on the nature of their surfaces, which causes more or less light to be reflected. There are different degrees of intensity of lustre, and also different kinds of lustre.

a. The kinds of lustre are six, and are named from some familiar object or class of objects.

1. *Metallic*—the usual lustre of metals. Imperfect metallic lustre is expressed by the term submetallic.

2. *Vitreous*—the lustre of broken glass. An imperfect vitreous lustre is termed subvitreous. Both the vitreous and subvitreous lustres are common. Quartz possesses the former in an eminent degree; calcite often the latter. This kind of lustre may be exhibited by minerals of any colour.

Lustre—continued.

3. *Resinous*—lustre of the yellow resins. Example, some opal, zinc blende.

4. *Pearly*—like pearl. Example, talc, native magnesia, stilbite, &c. When united with submetallic lustre the term metallic-pearly is applied.

5. *Greasy*—looking as if smeared with oil. Example, elæolite, some quartz.

6. *Silky*—like silk; it is the result of a fibrous structure. Example, fibrous calcite, fibrous gypsum, and many fibrous minerals, more especially those which in other forms have a pearly lustre.

7. *Adamantine*—the lustre of the diamond. When sub-metallic, it is termed metallic adamantine. Example, some varieties of white lead-ore or cerussite.

b. The degrees of intensity are denominated as follows:—

1. *Splendent*—when the surface reflects light with great brilliancy and gives well-defined images. Example, crystals of hematite, cassiterite, some specimens of quartz and pyrite.

2. *Shining*—when an image is produced, but not a well-defined image. Example, calcite, celestite.

3. *Glistening*—when there is a general reflection from the surface, but no image. Example, talc.

4. *Glimmering*—when the reflection is very imperfect, and apparently from points scattered over the surface. Example, flint, chalcedony.

A mineral is said to be *dull* when there is a total absence of lustre. Example, chalk.

COLOUR. (Dana.)

1. *Kinds of Colour.*—In distinguishing minerals, both the external colour and the colour of a surface that has been rubbed or scratched, are observed. The latter is called the streak, and the powder abraded, the streak-powder.

The colours are either metallic or unmetallic.

The metallic are named after some familiar metal, as copper-red, bronze-yellow, brass-yellow, gold-yellow, steel-grey, lead-grey, iron-grey.

The unmetallic colours used in characterising minerals are various shades of white, grey, black, blue, green, yellow, red, and brown.

There are thus snow-white, reddish-white, greenish-white, milk-white, yellowish-white.

Bluish-grey, smoke-grey, greenish-grey, pearl-grey, ash-grey.

Velvet-black, greenish-black, bluish-black, greyish-black.

Azure-blue, violet-blue, sky-blue, indigo-blue.

Emerald-green, olive-green, oil-green, grass-green, apple-green, blackish-green, pistachio-green (yellowish).

Colour—continued.

Sulphur-yellow, straw-yellow, wax-yellow, ochre-yellow, honey-yellow, orange-yellow.

Scarlet-red, blood-red, flesh-red, brick-red, hyacinth-red, rose-red, cherry-red.

Hair-brown, reddish-brown, chestnut-brown, yellowish-brown, pinchbeck-brown, wood-brown.

A play of colours.—This expression is used when several prismatic colours appear in rapid succession on turning the mineral. The diamond is a striking example; also precious opal.

Change of colours—when the colours change slowly on turning in different positions, as in labradorite.

Opalescence—when there is a milky or pearly reflection from the interior of a specimen, as in some opals, and in cat's-eye.

Iridescence—when prismatic colours are seen within a crystal; it is the effect of fracture, and is common in quartz.

Tarnish—when the surface colours differ from the interior; it is the result of exposure. The tarnish is described as irised when it has the hues of the rainbow.

3. *Asterism.*—Some crystals, especially the hexagonal, when viewed in the direction of the vertical axis, present peculiar reflections in six radial directions. This arises either from peculiarities of texture along the axial portions, or from some impurities. A remarkable example of it is that of the asteriated sapphire, and the quality adds much to its value as a gem. The six rays are sometimes alternately shorter, indicating the rhombohedral character of the crystal.

4. *Phosphorescence.*—Several minerals give out light either by friction or when gently heated. This property of emitting light is called phosphorescence.

Two pieces of white sugar struck against one another give a feeble light, which may be seen in a dark place. The same effect is obtained on striking together fragments of quartz; and even the passing of a feather rapidly over some specimens of zinc-blende is sufficient to elicit light.

Fluorite is the most convenient mineral for showing phosphorescence by heat. On powdering it and throwing it on a plate of metal heated nearly to redness, the whole takes a bright glow. In some varieties the light is emerald-green; in others, purple, rose, and orange. A massive fluor, from Huntington, Connecticut, shows beautifully the emerald-green phosphorescence. Some kinds of white marble, treated in the same way, give out a bright-yellow light. After being heated for a while the mineral loses its phosphorescence; but a few electric shocks will, in many cases, to some degree restore it again.

ELECTRICITY AND MAGNETISM. (Dana.)

Electricity.—Many minerals become electrified on being rubbed, so that they will attract cotton and other light substances; and when electrified, some exhibit positive and others negative electricity when brought near a delicately suspended magnetic needle. The diamond, whether polished or not, always exhibits positive electricity, while other gems become negatively electric in the rough state, and positively only in the polished state. Some minerals, thus electrified, retain the power of electric attraction for many hours, as topaz, while others lose it in a few minutes.

Many minerals become electric when heated, and such species are said to be pyroelectric, from the Greek *pur*, fire, and electric.

A prism of tourmaline, on being heated, becomes polar, opposite electricity being developed in the extremities by the heat. The prisms of tourmaline have different secondary planes at the two extremities.

Several other minerals have this peculiar electric property, especially boracite and topaz, which, like tourmaline, are hemihedral in their modification. Boracite crystallises in cubes, with only the alternate solid angles similarly replaced. Each solid angle, on heating the crystals, become an electric pole; the angles diagonally opposite are differently modified, and have opposite polarity. Pyroelectricity has been observed also in crystals that are not hemihedral, and in many mineral species. In some cases the number of poles is more than two. In prehnite crystals a large series occur distributed over the surface.

Magnetism.—The name lodestone is given to those specimens of an ore of iron called magnetite which have the power of attraction like a magnet; it is common in many beds of magnetite. When mounted like a horseshoe-magnet, a good lodestone will lift a weight of many pounds. This is the only mineral that has decided magnetic attraction. But several ores containing iron are attracted by the magnet, or, when brought near the magnetic needle, will cause it to vibrate; and moreover, the metals nickel, cobalt, manganese, palladium, platinum, and osmium, have been found to be slightly magnetic.

Many iron-bearing minerals become attractable by the magnet after being heated that are not so before heating. This arises from a change of part or all of the iron to the magnetic oxide.

FLAVOUR AND ODOUR. (Dana.)

Flavour belongs only to the soluble minerals. The kinds are—

1. *Astringent*—that of vitriol.
2. *Sweetish-astringent*—that of alum.

Flavour and Odour—continued.

3. *Saline*—that of common salt.
4. *Alkaline*—that of soda.
5. *Cooling*—that of saltpetre.
6. *Bitter*—that of Epsom salts.
7. *Sour*—that of sulphuric acid.

Odour is not given off by minerals in the dry, unchanged state, except in the case of a few gases and soluble minerals. By friction, moistening with the breath, the action of acids, and the blowpipe, odours are sometimes obtained which are thus designated:—

1. *Alliaceous*—the odour of garlic. It is the odour of burning arsenic, and is obtained by friction, and more distinctly by means of the blowpipe, from several arsenical ores.

2. *Horse-radish odour*—the odour of decaying horse-radish. It is the odour of burning selenium, and is strongly perceived when ores of this metal are heated before the blowpipe.

3. *Sulphureous*—odour of burning sulphur. Friction will elicit this odour from pyrites, and heat from many sulphides.

4. *Fetid*—the odour of rotten eggs or sulphuretted hydrogen. It is elicited by friction from some varieties of quartz and limestone.

5. *Argillaceous*—the odour of moistened clay. It is given off by serpentine and some allied minerals when breathed upon. Others, as pyrargillite, afford it when heated.

CRYSTALLINE AGGREGATES. (Dana.)

The crystalline aggregates here included are the simple, not the mixed; that is, they are those consisting of crystalline individuals of a single species.

The crystalline individuals may be (1) distinct crystals; (2) fibres or columns; (3) scales or lamellæ; or (4) grains, either cleavable or not so.

1. *Consisting of distinct crystals.*—The distinct crystal may be either long or short prismatic, stout or slender to acicular (needle-like), and capillary (hair-like); or they may have any other forms of crystals. They may be aggregated (*a*) in lines; (*b*) promiscuously with open spaces; (*c*) over broad surfaces; (*d*) about centres. The various kinds of aggregates thus made are:—

a. Filiform.—Thread-like lines of crystals, the crystals often not well defined.

b. Dendritic.—Arborescent slender spreading branches, somewhat plant-like, made up of more or less distinct crystals, as in the frost on windows, and in arborescent forms of native copper, silver, gold, &c.

Crystalline Aggregates—continued.

c. Reticulated.—Slender prismatic crystals promiscuously crossing, with open spacings.

d. Divergent.—Free crystals radiating from a central point.

e. Drusy.—A surface is drusy when covered with implanted crystals of small size.

2. *Consisting of columnar individuals.*

a. Columnar, when the columnar individuals are stout.

b. Fibrous, when they are slender.

c. Parallel fibres, when the fibres are parallel.

d. Radiated, when the columns or fibres radiate from centres.

e. Stellated, when the radiations from a centre are equal around, so as to make star-like or circularly-radiated groups.

f. Globular, when the radiated individuals make globular or hemispherical forms, as in wavellite.

g. Botryoidal, when the globular forms are in groups, a little like a bunch of grapes. The word is from the Greek for a bunch of grapes.

h. Mammillary, having a surface made up of low and broad prominences. The term is from the Latin *mammilla*, a little teat.

i. Coralloidal, when in open-spaced groupings of slender stems, looking like a delicate coral. A result of successive additions at the extremity of a prominence, lengthening it into cylinders, the stems generally having a faintly radiated structure.

Specimens of all these varieties of columnar structure, excepting the last, often having a drusy surface, the fibres or columns ending in projecting crystals.

3. *Consisting of scales or lamellæ.*

a. Plumose, having a divergent arrangement of scales, as seen on a surface of fracture; plumose mica.

b. Lamellar, tabular, consisting of flat lamellar crystalline individuals, superimposed and adhering.

c. Micaceous, having a thin fissile character, due to the aggregation of scales of a mineral which, like mica, has eminent cleavage.

d. Septate, consisting of openly-spaced intersecting tabular individuals; also divided into polygonal portions by reticulating veins or plates. A septarium is a concretion, usually flattened spheroidal in shape, the solid interior of which is intersected by partitions; these partitions are the fillings of cracks in the interior that were due to contraction on drying. Such septate concretions, especially when worn off at surface, often have the appearance of a turtle's back, and are sometimes taken for petrified turtles.

4. *Consisting of Grains. Granular structure.*—A massive mineral may be coarsely granular or finely granular, as in varieties of marble, granular quartz, &c. It is termed saccharoidal when evenly granular, like loaf-sugar. It may also be cryptocrystalline, that is, having no distinct grains that can be detected by the unaided eye, as in flint. The term cryptocrystalline is from the Greek for concealed crystalline. Aphanitic, from the Greek for

Crystalline Aggregates—continued.

invisible, has the same signification. The term ceroid is applied when this texture is connected with a waxy lustre, as in some common opal.

Under this section occur also globular, botryoidal, and mammillary forms, as a result of concretionary action in which no distinct columnar interior structure is produced. They are called pisolitic when in masses consisting of grains as large as peas (from the Latin *pisum*, a pea), and oölitic when the grains are not larger than the roe of a fish, from the Greek for egg.

5. *Forms depending on mode of deposition.*—Besides the above, there are the following varieties which have come from mode of deposition:—

a. Stalactitic, having the form of a cylinder, or cone, hanging from the roofs of cavities or caves. The term stalactite is usually restricted to the cylinders of calcium carbonate hanging from the roofs of caverns; but other minerals are said to have a stalactitic form when resembling these in their general shape and origin. Chalcedony and limonite are often stalactitic. Interiorly the structure may be either granular, radiately fibrous, or concentric.

The waters percolating through the roofs of limestone caverns hold some limestone in solution; and the deposit which each successive drop of water makes, lengthens out the cylinder; and not unfrequently they become yards in length, or reach from roof to floor. The stalactites are sometimes hollow cylinders when small, because the drops, which follow one another very slowly, evaporate chiefly at the outer margin of each, the first one thus making a ring, and the following lengthening the ring into the cylinder. The solution is strictly a solution of calcium bicarbonate; as evaporation takes places the excess of carbonic acid goes off and calcium carbonate is deposited.

b. Concentric.—When consisting of lamellæ, lapping one over another around a centre, a result of successive concretionary aggregations, as in many concretionary forms, most pisolite, part of oölite, some stalactites, &c.

c. Stratified, consisting of layers, as a result of deposition: e. g. some travertine, or tufa.

d. Banded, straticulate; colour-stratified. Like stratified in origin, but the layers thin and usually indicated only by variations in colour or texture; the banding is shown in a transverse section: e. g., agate, much stalagmite, riband jasper, some limestone; it becomes lamellar or slaty when the little layers are separable.

e. Geodes.—When a cavity has been lined by the deposition of mineral matter, but not wholly filled, the enclosing mineral is called a geode. The mineral is often banded, owing to the sucessive depositions of the material, and frequently has its inner surface set with crystals. Agates are often slices or fragments of geodes.

6. *Fracture.*—Kinds of fracture in these crystalline aggregates

Crystalline Aggregates—continued.
depend on the size and form of the particles, their cohesion, and to some extent their having cleavage or not.

Among granular varieties, the influence of cleavage is in all cases very small, and in the finest almost or quite nothing. The term "hackly" is used for the surface of fracture of a metal, when the grains are coarse, hard, and cleavable, so as to be sharp and jagged to the touch; even, for any surface of fracture when it is nearly or quite flat, or not at all conchoidal; conchoidal, when the mineral, owing to its extremely fine or cryptocrystalline texture, breaks with shallow concavities and convexities over the surface, as in the case of flint. The word conchoidal is from the Latin *concha*, a shell. These kinds of fracture are not of great importance in mineralogy, since they distinguish varieties of minerals only, and not species.

FUSIBILITY. (Foye.)

1. Stibnite (grey antimony). Fusible in coarse splinters in the summit of a candle-flame without the blow-pipe.
2. Natrolite. Fusible in fine splinters in the summit of a candle-flame without the blow-pipe.
3. Almandite (iron-alumina-garnet). Does not fuse in the candle-flame. Fuses easily before the blow-pipe in obtuse pieces.
4. Green Actinolite. Fusible before the blow-pipe in coarse splinters.
5. Orthoclase. Fusible before the blow-pipe in fine splinters.
6. Bronzite. Before the blow-pipe, becomes rounded only on the sharp edges.

Table

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.
Diamond	10	..	Transparent to translucent.	Adamantine	White to shades of yellow, orange, red, blue, green, brown, black.
Emerald	7½-8	Brittle	Transparent to subtranslucent	Vitreous to resinous.	Rich green
Lapis-lazuli	5½	..	Transparent to opaque.	Vitreous	Rich blue
Opal	5½-6½	..	Rich play of colours when turned.	Waxy to sub-vitreous.	White, grey, yellow, brown, red, green, blue.
Sapphire	9	Very tough	Transparent to translucent.	..	Blue as a rule.
Topaz	8	..	Transparent to subtranslucent	Vitreous	Pale yellow.
Turquoise	6	..	..	Waxy	Bluish green.

134.

Electricity and Magnetism.	Structure.	Sp. gr.	B.B.	Solubility.	Composition.	Application.
Vitreous electric when rubbed.	Crystalline, isometric.	3·00–3·55	Burns away as carbonic acid gas.	Insoluble	Pure carbon	Jewelry, cutting and drilling.
..	Crystalline, hexagonal.	2·67–2·75	Clouded, but not fused.	Insoluble	Silica 62 Alumina 19 Beryllium oxide 16	Jewelry.
..	Massive, rarely crystalline (isometric).	2·3–2·5	Fuses to white glass.	When powdered and calcined losescolour in acids.	Silica 45 Alumina 32 Soda 9 Lime 3 Iron 1 Sulphuric acid 6 Sulphur 1	Jewelry. Ornaments, Mosaics.
..	Compact, amorphous.	1·9–2 3	..	In strong alkaline solution.	Silica	Jewelry.
..	Crystalline, rhombohedral.	3·94–4·16	Unaltered both alone and with soda.	..	Aluminium 53 Oxygen 47	Jewelry.
Pyro-electric	Crystalline, orthorhombic.	3·4–3·65	Infusible	Insoluble in acids.	Alumina 57 Silica 34 Fluorine 15	Jewelry.
..	Massive ..	2·6–2·8	Infusible, becomes brown, colours flame green.	In hydrochloric acid.	Phosphorus 22½ Alumina 47 Water 20½	Jewelry.

Tabl

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
ALUMINIUM—							
Alum shale ..	..	..	..	..	..	..	..
Alum stone ..	4	..	Transparent to translucent.	Vitreous to pearly.	White to reddish.	..	..
Corundum ..	9	Exceedingly tough.	Transparent to translucent.	..	Blue to black.	..	..
Cryolite ..	..	..	Translucent	..	White	..	..
Emery	9	Exceedingly tough.	Transparent to translucent.	..	Black	..	..
ANTIMONY ..	3–3½	Brittle	..	..	White	White	..
Stibnite ..	2	Brittle	..	Shining	Grey	Grey, tarnishes	..
BARIUM—							
Barytes ..	2½–3½	..	Transparent to translucent.	Vitreous to pearly.	White	..	..
Witherite ..	3½	Brittle	Transparent to translucent.	Resinous	Dirty white.	..	..
BISMUTH	2–2½	Brittle	..	..	White	White	..
CHROMIUM—							
Chromite ..	5½	..	..	Submetallic	Brownish black.	Dark brown.	Magne in sma fragme

135

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application.
..	..	..	..	..	..	..	..
..	Massive and crystalline (rhombo-hedral).	2·58–2·75	Infusible, decrepitates.	..	In sulphuric acid complete without forming jelly.	Alumina 37 Potash 11 Sulphurous oxide 38 Water 13	Affords Roman alum, much prized by dyers.
..	Crystalline, rhombo-hedral.	3·94–4·16	Unaltered alone or with soda.	..	..	Pure alumina	Abrasive purposes.
..	Monoclinic	2·9–3·1	Fusible in candle-flame.	..	..	Fluorine 54 Sodium 33 Aluminium 13	Source of aluminium; used in soda and glass making.
..	..	3·94–4·16	Unaltered alone or with soda.	..	..	Alumina containing magnetic iron.	Abrasive purposes.
..	Crystalline, rhombo-hedral.	6·6–6·75	Fuses easily and vaporises.	..	..	Contains a little arsenic, iron, and silver as impurities.	Alloys and medicine.
..	Crystalline, ortho-rhombic.	4·5–4·62	Fuses in candle-flame; vaporises and gives white sulphurous fumes on charcoal.	..	..	Antimony 72 Sulphur 28	Chief source of antimony.
..	Crystalline, ortho-rhombic.	4·3–4·7	Fuses to a bead and colours flame green.	..	Insoluble in acids.	Baryta 66 SO_3 34	Common pigment.
..	Crystalline, ortho-rhombic.	4·29–4·35	Fuses to a bead and colours flame green; also decrepitates.	In HCl	Soluble in acids.	Baryta 78 CO_2 22	In sugar refining and plate-glass making.
..	Crystalline, rhombo-hedral.	9·7–9·8	Vaporises, leaving a yellow coating; fuses at 476° F.	..	..	Arsenic, sulphur, and tellurium as impurities.	Alloys.
..	..	..	Infusible alone; green bead with borax.	..	..	Chromium oxide 68 Iron oxide 32	Source of chrome green and chrome yellow; valuable pigments.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
COBALT—							
Black oxide..	..	..	..	..	Blue-black.	..	..
Bloom	1½–2	..	Transparent to translucent.	Pearly to none.	Red	..	..
Glance	5½–6	Brittle	..	..	White	Greyish	..
COPPER	2½–3	Ductile, malleable.	..	..	Reddish	..	..
Black	..	..	..	..	Black	..	..
Blue vitriol ..	2–2½	..	Subtrans-parent to translucent.	Vitreous	Deep blue.	Unco-loured.	..
Glance	2½–3	..	..	..	Grey	Grey	..
Grey	3–4½	..	..	..	Grey to blackish.	..	..
Horseflesh ore	3	Brittle	..	..	Reddish brown, tar-nishes.	Greyish black, shining.	..
Malachite (*a*)	3½–4	..	Opaque	..	Light green.	Pale green	..

—*continued.*

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application
..	Earthy	..	..	..	In HCl. giving chlorine fumes.	Cobalt oxide, 20–40 %	Pigment.
..	Crystalline, monoclinic	2·95	Fuses with arsenical fumes on charcoal; gives blue glass with borax.	..	..	Cobalt oxide 38 Arsenic acid 38 Water 24	Pigment.
..	Crystalline, isometric.	6·4–7·2	Fuses to globule, emitting arsenical fumes; gives metallic arsenic in closed tube.	..	..	23½ % cobalt to nil.	Pigment, and affords nickel.
..	..	8·8–8·95	Fuses readily at 1930° F., surface black on cooling.	..	In nitric acid, giving deep blue with ammonia.	A little silver as an impurity	Many industrial purposes both alone and in alloys.
..	Powder and in masses.	..	..	..	..	Copper oxide, giving 60–70 % metal.	Source of the metal.
Nauseous metallic taste.	Crystalline, triclinic.	2·21	..	..	..	Copper oxide 32 SO_3 32 Water 36	Source of the metal, and used in dyeing, calico printing, and as an antiseptic.
..	Crystalline, orthorhombic.	5·5–5·8	Fuses readily, giving sulphur fumes leaving metallic globule.	..	In hot nitric acid.	Copper 80 Sulphur 20	Source of the metal.
..	..	4·7–5	..	..	..	Often contains silver.	Source of the metal.
..	Crystalline, isometric.	4·4–5·5	Fuses to brittle magnetic globule.	..	In nitric acid.	Copper 55½ Iron 16½ Sulphur 28½	Source of the metal.
..	Crystalline, monoclinic.	3·7–4	Decrepitates, colours flame green and forms black slag; with borax fuses and gives metallic bead	In nitric acid.	In nitric acid.	Copper oxide 72 CO_2 20 Water 8	Source of the metal, and in ornamentation.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
COPPER—							
Malachite (b)	3½–4½	Brittle	Transparent to opaque.	Vitreous to adamantine.	Deep blue.	Bluish	..
Pyrites	3½–4	Brittle	..	..	Yellow, irides-cent, darker colour richer in copper.	Greenish black.	..
Silicate	2–4	..	Translucent to opaque.	Shining to earthy.	Bluish green.	..	..
GOLD	2½–3	Very ductile and malleable.	..	..	Yellow to whitish.	..	..
Calaverite ..	..	..	..	..	Bronze yellow.	..	..
Sylvanite ..	1½–2	..	..	..	Grey to yellow.	Grey to yellow.	..
IRON—							
Hematite ..	5½–6½	..	..	Splendent when crystallised.	Grey to black.	Reddish brown.	Sometimes slightly magnetic.
Limonite ..	5–5½	..	..	Submetallic to earthy.	Blackish to yellow.	Yellowish.	..
Magnetite ..	5½–6½	Brittle	..	..	Black	Black	Strongly magnetic.
Siderite.. ..	3–4½	..	Translucent to opaque.	Pearly	Greyish to brownish red.	..	..

—*continued.*

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application
..	Crystalline, monoclinic.	3·5–3·83	Decrepitates, colours flame green and forms black slag; with borax fuses and gives metallic bead.	In nitric acid.	In nitric acid.	Copper oxide 70 CO_2 23 Water 5	Source of metal.
..	Crystalline, tetragonal.	4·15–4·3	Gives sulphur fumes; and metallic globule of copper and iron with soda on charcoal.	..	In nitric acid.	Copper 34½ Iron 30½ Sulphur 35	Sulphur burned off to make sulphuric acid and cinders treated for copper.
..	Massive; incrustations.	2–2·4	Gives water without melting; affords metallic globule with soda on charcoal.	..	..	Copper oxide 45 Silica 34 Water 20	Gives 10–30% of metal.
..	..	19–19·3	Melts without odour at 2016° F.	..	In aqua regia.	Always contains some silver.	Coin, jewelry, &c.
..	Massive	9·043	..	..	..	Tellurium 55½ Gold 44½	Source of gold.
..	..	7·9–8·33	..	..	..	Tellurium 56 Gold 28½ Silver 15½	Source of gold.
..	Crystalline, rhombohedral, to massive and earthy.	4·5–5·3	Infusible, becomes magnetic.	..	..	Iron 70 Oxygen 30	Valuable source of metal; earthy varieties used as pigments.
..	Massive to earthy.	..	Blackens and becomes magnetic; forms a yellow glass with borax in outer flame.	..	..	Iron oxide 85½ Water 14½	Valuable source of metal; earthy varieties used as pigments.
..	Crystalline, isometric.	5–5·1	Infusible; gives yellow glass with borax in outer flame.	..	..	Iron 72½ Oxygen 27½	Valuable source of metal.
..	Crystalline, rhombohedral.	3·7–3·9	Infusible, blackens, becomes magnetic.	In HCl	In hot HCl	Iron oxide 62 Carbon oxide 38	Valuable source of metal.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
LEAD—							
Cerussite ..	3–3½	Brittle	..	Adamantine	White to dark grey.	..	..
Galena	2½	Fragile	..	Shining metallic.	Grey	Grey	..
MANGANESE—							
Fowlerite ..	5½–6½	..	Transparent to opaque.	Vitreous	Reddish to black.	..	..
Pyrolusite ..	2–2½	..	..	..	Black	Black, non-metallic.	..
MERCURY—							
Cinnabar ..	2–2½	Sectile	Subtransparent to opaque.	Dull to adamantine.	Red to brownish black.	Scarletto brownish.	..
NICKEL—							
Linnæite ..	5½	..	..	..	Grey	Grey	..
Millerite ..	3–3½	Brittle	..	..	Yellow	Bright	..
Niccolite ..	5–5½	Brittle	..	Metallic	Red	Red	..
Pyrrhotite ..	3½–4½	Brittle	..	..	Yellowish red.	Greyish black.	Slightly magnetic.
Smaltite, *see* Cobalt glance							

—*continued.*

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application.
..	Crystalline, ortho-rhombic.	6·46–6·48	Fuses, decrepitates, gives bead on charcoal with difficulty.	In dilute nitric acid.	In dilute nitric acid.	Lead oxide 83½ Carbon oxide 16½	Valuable source of metal.
..	Crystalline, isometric.	7·25–7·35	Fuses, decrepitates, emits sulphur, gives charcoal a yellow coating, and yields metallic bead.	..	..	Lead 86½ Sulphur 13½	Valuable source of metal; and often silver.
..	Crystalline, triclinic.	3·4–3·7	Deep violet borax bead, becoming reddish brown on cooling.	..	..	Manganese oxide 54 Silica 46	As an ornamental stone, and in staining glass and porcelain.
..	Crystalline, ortho-rhombic.	4·8	Deep violet borax bead, becoming reddish brown on cooling.	..	..	Manganese 63 Oxygen 37	In making bleaching powder.
..	Crystalline, rhombo-hedral.	8–9	Quite volatile	..	..	Mercury 86 Sulphur 14	Chief source of the metal.
..	Crystalline, isometric.	4·8–5	Gives sulphurous and arsenical fumes and affords metallic globule on charcoal.	..	..	Sulphur 42 Nickel and Cobalt, various	Source of nickel.
..	Crystalline, rhombo-hedral.	5·65	Fuses to globule on charcoal.	.	..	Nickel 64½ Sulphur 35½	Source of nickel.
..	Crystalline, hexagonal.	7·35–7·67	Fuses to globule, emits arsenical fumes.	..	In aqua regia.	Nickel 44 Arsenic 56	Source of nickel.
..	Crystalline, hexagonal.	4·5–4·65	Fuses and glows in inner flame, affording black magnetic globule.	..	..	Iron 60½ Sulphur 39½ Nickel, varying.	Source of nickel.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
PALLADIUM ..	4½–5	Ductile, malleable.	..	Steel-like when hammered.	Grey to white.	..	..
PLATINUM ..	4–4½	Ductile, malleable.	..	Metallic, shining.	Grey	Grey	Often magnetic.
SILVER	2½–3	Sectile, malleable.	..	..	White, shining.	White, shining.	..
Black	2–2½	Brittle	..	..	Black	Black	..
Embolite ..	1–1½	..	..	..	Green	..	..
Galena, *see* Lead, galena							
Glance	2–2½	Sectile	..	Metallic	Grey	Grey, shining.	..
Horn	1½–2	..	Transparent to opaque.	Resinous to adamantine.	Grey to greenish or bluish.	Shining	..
Polybasite ..	..	..	..	..	Blackish	..	..
Proustite ..	..	..	.	Splendent	Light red.	..	..
Ruby	2–2½	..	.	Splendent to adamantine.	Black to dark red.	..	..
STRONTIUM— Celestite ..	3–3½	Brittle	Transparent to translucent.	Vitreous to pearly.	Bluish white.	..	..

—*continued.*

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application.
..	..	11·3–12·2	Fuses with sulphur.	..	..	Contains platinum and iridium.	Forms valuable alloys for instruments.
..	Grains or masses.	16–19	Unaltered	..	Hot aqua regia.	..	Invaluable for instruments and chemical plant, used in electricity and photography.
..	Crystalline, isometric.	10·1–11·1	Easily fuses to white globule.	..	Nitric acid	Often contains copper, sometimes bismuth.	Coin, plate, &c.
..	Crystalline, ortho-rhombic.	6·27	Fumes of sulphur and antimony.	..	Dilute nitric acid.	Silver 68½ Antimony 15 Sulphur 16	Source of metal.
..	..	5·3–5·8	..	..	..	Silver chloride 59 „ bromide 41	Source of metal.
..	Crystalline, isometric.	7·19–7·4	Intumesces, emits sulphur and gives metallic bead on charcoal in outer flame.	..	..	Silver 87 Sulphur 13	Coin, plate, &c.
..	Crystalline, isometric.	..	Fuses in candle, emitting acrid fumes; gives metal on charcoal.	..	..	Silver 75 Chlorine 25	Source of metal.
..	Crystalline, ortho-rhombic.	6·214	..	..	..	Silver 64–72%	Source of metal.
..	..	5·4–5·6	Garlic odour	..	..	Silver 65½ Arsenic 15 Sulphur 19½	Source of metal.
..	Crystalline, rhombo-hedral.	5·7–5·9	Fuses very readily; gives white deposit on charcoal and metallic bead with soda.	..	..	Silver 60 Antimony 22½ Sulphur .. 17½	Source of metal.
..	Crystalline, ortho-rhombic.	3·9–4	Decrepitates and fuses, colouring flame red.	..	..	Strontia 56½ Sulphuric acid 43½	Colouring fireworks.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
STRONTIUM— Strontianite..	3½–4	Brittle	Transparent to translucent.	Vitreous to resinous.	Greenish white.	..	..
TELLURIUM ..	2–2½	Brittle	..	..	White	White	..
TIN— Ore	6–7	..	Translucent to opaque.	Adamantine	Brown to black.	Grey to brownish	..
Pyrites	4	Brittle	..	..	Grey to black.	Blackish	..
TITANIUM— Rutile	6–6½	Brittle	Transparent to opaque.	Submetallic to adamantine.	Reddish	Brownish.	..
TUNGSTEN— Wolfram ..	5–5½	..	..	Submetallic to shining.	Dark grey.	Reddish brown	..
URANIUM— Pitchblende..	5½	..	Opaque	Submetallic to dull.	Grey to black.	Black	..
Uran mica ..	2–2½	..	Transparent to subtranslucent.	Pearly	Green	Green	..
ZINC— Blende	3½–4	Brittle	Transparent to subtranslucent.	Resinous to waxy.	Yellow to black.	..	Frictionally electric.
Calamine ..	4½–5	Brittle	Transparent to subtranslucent.	Vitreous to pearly.	Dirty whitish.	..	Pyro-electric.

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
..	Crystalline, ortho-rhombic.	3·6–3·72	Swells but does not fuse; colours flame red.	In cold dilute acid.	..	Strontia 70 Carbonic acid 30	Colouring fireworks.
..	Crystalline, rhombo-hedral.	6·1–6·3	Fuses and volatilises on charcoal, giving green flame.	..	..	..	..
..	..	6·4–7·02	Infusible alone; with soda on charcoal gives metallic bead	..	..	Tin 78⅔ Oxygen 21⅓	Source of metal.
..	..	4·3–4·6	..	..	..	Tin 27 Copper 30 Iron 13 Sulphur 30	Source of metal.
..	Crystalline, tetragonal.	4·18–4·25	Unaltered alone.	..	..	Titanium 61 Oxygen 39	Enamelling porcelain and teeth.
..	Crystalline, monoclinic.	7·1–7·5	Fuses easily to magnetic globule.	..	Aqua regia	Tungsten oxide 76½ Manganese oxide 14 Iron oxide 9½	Alloys with iron.
..	Crystalline, sometric.	6·4–9·3	Infusible; grey slag with borax.	..	Powder slowly in nitric acid.	Uranium 81½ Lead 4 Iron ½ Oxygen 13½ Water ½	Enamelling porcelain.
..	Crystalline, tetragonal.	3·3–3·6	Fuses to blackish mass; colours flame green.	..	..	Uranium oxide 61 Phosphorus oxide 15 Copper „ 8½ Water „ 15½	Enamelling porcelain.
..	Crystalline, isometric.	..	Nearly infusible alone or with borax. Zinc fumes when strongly heated on charcoal.	..	Nitric acid	Zinc 67 Sulphur 33	Source of metal.
..	Crystalline, ortho-rhombic.	3·16–3·9	Infusible alone; clear glass with borax.	..	Hot sulphuric acid, gelatinising.	Zinc oxide 67½ Silica 25 Water 7½	Source of metal.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
ZINC— Goslarite ..	2–2½	Brittle	..	Vitreous	White	..	..
Smithsonite ..	5	Brittle	Subtransparent to translucent.	Vitreous to pearly.	Dirty white.	..	Frictionally electric, negative.
Willemite ..	5½	Brittle	Transparent to opaque.	..	Dirty white.	..	..
Zincite	4–4½	..	Translucent	Brilliant to subadamantine.	Red	Yellow.	..

Table

NON-METALLIFEROUS

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
APATITE ..	5	Brittle	Transparent to opaque.	Vitreous to resinous.	Greenish	..	Frictionally electric.
ARSENIC.. ..	3·5	Brittle	..	..	Dirty white.	Dirty white.	..
Mispickel ..	5½–6	Brittle	..	Shining	White	Grey	..
Orpiment ..	1½–2	Sectile	Transparent to translucent.	Pearly	Yellow	Yellow	..
Realgar ..	1½–2	..	Transparent to translucent.	..	Orange to red.	..	..

—*continued.*

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application.
Astringent, metallic, nauseous	Crystalline, ortho-rhombic.	2·036	Zinc fumes on charcoal.	..	Easily	Zinc oxide 28 Sulphuric acid 28 Water 44	Dyeing, and as a disinfectant.
..	Crystalline, rhombo-hedral.	4·3–4·45	Infusible alone; finally vaporises.	..	..	Zinc oxide 65 Carbonic acid 35	Source of metal.
..	Crystalline, rhombo-hedral.	3·89–4·18	Difficultly fusible to white enamel	In nitric acid	In HCl gelatinises	Zinc oxide 73 Silica 27	Source of metal.
..	Crystalline, hexagonal.	5·68–5·74	Infusible alone; yellow transparent bead with borax.	..	In nitric acid.	Zinc 80 Oxygen 20	Source of metal.

136.

MINERALS.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application
..	Hexagonal	3·18–3·25	Fusible only on edges.	None	Slowly in nitric acid.	Phosphorus oxide 41 Lime 54 Chlorine or Fluorine	Artificial manures.
..	Rhombo-hedral.	5·65–5·95	Readily volatilises, with garlic odour.	..	..	..	In alloys.
..	Ortho-rhombic.	5·67–6·3	Arsenical fumes, magnetic globule.	..	..	Arsenic 46 Iron 34½ Sulphur 19½	Affords arsenic and often cobalt and gold.
..	Ortho-rhombic.	3·4–3·5	Evaporates with garlic odour; burns with blue flame on charcoal.	..	..	Arsenic 61 Sulphur 39	Pigment.
..	..	3·35–3·65	Evaporates with garlic odour; burns with blue flame on charcoal.	..	..	Arsenic 70 Sulphur 30	Pyrotechny.

Table 136

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
ARSENIC—							
White	1½	..	..	..	White	..	..
ASBESTOS ..	..	..	Translucent	Vitreous to pearly.	White to brownish green	..	..
BORATES—							
Lime	3	..	..	..	..	..	..
Lime-soda ..	1	..	..	Silky	Dirty white.	..	..
Magnesia ..	7	..	..	Vitreous	Dirty white.	..	Pyro-electric.
Soda	2–2½	..	Transparent	Vitreous	White	..	..
CALCSPAR ..	3	..	..	Silky to vitreous and earthy.	White to nearly black.	..	..
EPSOM SALT ..	..	..	..	Vitreous to earthy.	White	..	..
FLUOR SPAR ..	4	Brittle	Transparent to sub-translucent.	..	Greenish purplish, yellowish.	..	..
GRAPHITE ..	1–2	Flexible in thin laminæ.	..	Metallic	Black to grey.	Soils paper.	..
GYPSUM	1½–2	..	Transparent to opaque.	Pearly	Dirty white.	..	..

—*continued.*

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application.
Sweetish astringent.	Isometric	3·7	..	..	Readily	Arsenic 76 Oxygen 24	Medicine.
..	Fibrous, silky.	2·9–3·4	Unalterable	..	..	..	Fireproofing.
..	..	2·262–2·48.	..	..	..	..	Borax (borate of soda) is much used in medicine and for preserving foods; the other borates are converted into borax for similar uses.
..	Fibrous	1·65	Fuses very easily.	..	..	..	
..	Isometric	2·97	Easily fused; intumesces; colours flame green.	..	In HCl.	Boron oxide 62 Magnesia 31 Chlorine 7	
Sweetish alkaline.	..	..	Swells enormously, becomes opaque, and finally forms glassy bead.	..	..	Boron oxide 36½ Soda 16½ Water 47½	
..	..	2·5–2·8	Infusible; colours flame reddish; becomes caustic.	Dilute cold HCl	..	Lime 56 Carbonic acid 44	Common forms, as chalk and limestone, afford lime; marbles used in ornamental buildings; Iceland spar used in optical instruments.
Saline bitter.	..	..	..	..	Very readily.	Magnesia 16½ Sulphuric acid 32½ Water 51	Medicine.
..	Isometric	3–3·25	Decrepitates; fuses to an enamel.	..	Powder in sulphuric acid.	Fluorine 49 Calcium 51	As a flux; for carving; vapour etches glass.
Greasy touch.	Hexagonal	2·25–2·27	Infusible	..	Insoluble	Carbon 95–99%	Crucibles, furnaces, pencils.
..	Monoclinic	2·33	Exfoliates; becomes white and opaque; forms globule.	..	Quietly in HCl.	Lime 32½ Sulphuric acid 46½ Water 21	For carving; manure; and plaster of Paris.

Table 136

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
INFUSORIAL EARTH	..	..	..	..	Dirty white.	..	..
KAOLIN	1–2½	Flexible	..	..	Dirty white.	..	..
MEERSCHAUM	2–2½	..	..	..	Whitish	..	..
MICA	2–2½	Tough, elastic.	Transparent to translucent.	Pearly	Yellowish brown.	..	..
NITRATES— Potash	2	..	..	..	Dirty white.	..	..
Soda	..	..	..	..	Dirty white.	..	..
SALT	2	..	..	..	Dirty white.	..	..
SULPHUR ..	1½–2½	Brittle	Transparent to translucent.	Resinous	Yellow	Yellow	..
Pyrites	6–6½	Brittle	..	Metallic	Yellow	Brownish.	..
TALC	1–1½	Flexible	..	Pearly	Greenish	..	..

—*continued.*

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Efferv-escence.	Solubility.	Composition.	Application.
..	Earthy	..	..	..	..	Silica	Polishing; boiler covering; making soluble silica
Greasy touch.	Ortho-rhombic.	2·4–2·6	Infusible	..	Insoluble	Alumina 40 Silica 46 Water 14	Porcelain; paper-making.
Smooth touch.	..	Floats on water.	Infusible	..	..	Silica 61 Magnesia 27 Water 12	Pipe bowls.
..	Monoclinic	2·7–3	Whitens; fuses only on thinnest edges.	..	..	Silica 46 Alumina 36 Iron 4 Potash 9 Water 2	In heat-resisting structures.
Saline, cooling.	Ortho-rhombic.	1·97	Burns vividly.	..	In water	Potash 46½ Nitrogen oxide } 53½	Explosives; nitric acid; pyrotechnics
Saline, cooling.	Rhombo-hedral.	..	Burns vividly; deliquesces.	..	In water	Soda 36½ Nitrogen oxide } 63½	Making nitric & sulphuric acids; manures.
Saline	Isometric	2·257	Fuses easily; decrepitates; colours flame yellow.	..	In water	Chlorine 61 Sodium 39	Domestic; agricultural; industrial.
..	Ortho-rhombic.	2·07	Burns with blue flame and sulphurous odour.	..	..	..	Bleaching; gunpowder; sulphuric acid.
..	Isometric	4·8–5·2	Emits sulphur; affords magnetic globule.	..	..	Sulphur 53 Iron 47	Green vitriol; sulphuric acid; alum.
Greasy touch.	Ortho-rhombic.	2·5–2·8	Infusible	..	Insoluble	Silica 63 Magnesia 33 Water 3	Polishing; lubricating; fire resisting; porcelain; weighting paper and soap.

ASSAYING.

ASSAYING: *Auriferous Mineral.* *a.* (Foord.)

The auriferous nature or otherwise of quartz may be readily ascertained by means for the most part mechanical; and we may often gain an insight into the mode of occurrence of the precious metal, and consequently as to the treatment which such a quartz would require in the mill. The mode of procedure is simply this. First pulverise the sample in a large cast-iron mortar, with a very stout bottom; the pestle of wrought iron may be 4 ft. long, and weigh 13 lb., and the upper part of this pestle, for preservation of the hands, should be covered with a short piece of rubber hose pipe. Employ a sieve of brass wire of fine mesh (say about 900 to the sq. in.), and after all the sample has passed through the sieve, grind the powder still finer in a shallow cast-iron mortar of about 11 in. diameter and 5 in. deep. Then submit a weighed quantity of the very finely ground sample to careful washing in a porcelain dish, and you will eventually obtain a residue consisting almost entirely of the metallic sulphides of the ore. These, small in bulk in proportion to that of the original quartz sample, are next transferred to a large agate mortar, again ground and washed alternately, until at last a small grey residue showing no gold is all that remains. This grey residue consists almost entirely of particles of cast and wrought-iron abraded during the preceding operations. They may be easily separated. A darning needle or a steel pen is magnetised by drawing it once or twice, always in the same direction, over the surface of an ordinary horse-shoe magnet, and to the little steel magnet thus obtained the particles of iron will attach themselves, and may be freed from any entangled particles of gold by drawing them backwards and forwards through the water with which the agate mortar is filled. The agate mortar is pre-eminently suitable for this final work; the smallest particle of gold can be seen against the dull surface of the agate; the hardest materials can be ground impalpably in the little vessel, and it serves the double capacity of mortar and wash-bowl; we can wash and grind alternately to the close of the operation. When the gold is finally separated in spangles or flattened particles in the agate mortar, accessory chemical means for refining and collecting the precious metal into a globule may be employed. The gold residue may be wrapped in a morsel of sheet-lead and cupelled before the blowpipe; and from the diameter of the resulting minute spherical bead of fused gold thus obtained, its weight may be easily computed. Such operations would in most cases prove inapplicable in the hands of the miner in the field. But by the purely mechanical treatment, the miner can ascertain whether the sample tried is auriferous or not, and even without attempting to weigh the sepa-

Auriferous Mineral—continued.
rated gold, he will be able to draw valuable conclusions from its aspect in the mortar, concerning the comparative richness of the stone.

ASSAYING: *Auriferous Mineral. b.* (Panning.)

The estimation of the value of an auriferous material in which the gold is contained in a free state, can be done sometimes in a more satisfactory manner by simple appliances than in the best appointed laboratory. This is especially the case with low grade material, and arises from the fact that a laboratory assay can only be made on small samples, and that small samples cannot possibly be made to accurately represent the bulk, because the presence or absence of a small particle of gold in or from the same will suffice to disturb the basis of calculation. Panning more nearly resembles the operations which are put in practice when working the material as an industrial undertaking, and is therefore in many cases to be preferred. Of course, to be reliable, it must be done by an expert.

The implement most commonly used is the ordinary miners' pan, a circular dish of Russia sheet iron, about 12 in. wide, and 3 in. deep, with sloping sides. There should be a slight indentation all round where the sides join the bottom, so as to afford lodging for the gold grains, and the rustier it is the better. The Brazilian batea, made of hard wood in a solid piece, and hollowed out like a shallow funnel, is a superior implement when in capable hands. Another good substitute for this pan is a kind of magnified shovel, without handle, made of linden wood, and provided with a vertical wall on three sides. The wooden implements should be slightly charred on the surface to show up the gold grains, and should not have been used to hold mercury or amalgam. Absolute cleanliness is essential.

The sample to be treated, which should preferably be an exact quantity, say 5 to 25 lb., representing 100–500 assay tons, is crushed till it is fine enough to pass through a 60-mesh sieve, then moistened with water in the pan or other implement. The operator stands beside a tub filled with clean water, with strips across the top for the pan to rest on. Washing with a pan consists in gradually getting rid of the refuse matters by means of the water, the greater weight of the valuable portions enabling them to resist the tendency to be washed away. The greatest care must be taken that all parts of the mass be thoroughly washed by mixing up and squeezing in the hand, especially if any clay is present or other matter tending to increase the cohesiveness of the mass.

Successive small quantities of refuse are washed off and fresh portions of water taken on till the bulk is reduced to a small deposit of heavy matters, which may include magnetic iron, tin, bismuth, pyrites, platinum, and gold. The washing is done by means of a circular motion combined with a jerk or twist which helps the heavy particles to become dissociated from the light. A

Auriferous Mineral—continued.
sufficiency of water to keep the whole mass quite wet must be maintained throughout the operation. As the end approaches, a useful help is a bullock's horn with the small end plugged and then perforated so as to allow of a tiny and regular stream of water flowing out when the horn is filled by dipping it into the tub. By directing this little stream with care, the valuable particles can be collected in a small space by themselves. Then on being dried and weighed, they will give a very fair approximate idea of the value of the material treated. But a much more accurate estimate may be made by following the directions given by Brown in his 'Manual of Assaying':—

"If gold alone is obtained, that is, gold (or gold and silver) free from sulphurets, etc., it must be treated as an alloy, weighed, parted and weighed again, or cupelled with lead, weighed, parted and weighed; in both cases giving gold and silver.

"If the panning is not carried to such a point as to get rid of all the rock, the concentration is all scorified with test lead (or run down in a crucible), cupelled, parted and weighed. In the case of an ore supposed to carry auriferous sulphurets, it should be panned so far as can safely be done without losing metalliferous particles, and the concentration treated as above described.

"If the ore is quite poor, or a large quantity is desired to be worked, the panning can be carried on roughly, and the successive concentrations finally panned together.

"The results are based upon the amount of ore taken in the pan. If much of this work was to be done, a set of weights from 500 assay tons down (approximately accurate) would be very convenient and save calculation. The result would be as many times the number of oz. contained in the ore as the quantity of ore was more than 1 A.T.

"For example, the ore was supposed to be very poor and therefore 500 A. T. were taken. Bead weighed 50 mgrm.

$$\therefore 500 \text{ A. T.} : 1 \text{ A. T.} :: 50 \text{ mgrm.} : \tfrac{1}{10} \text{ mgrm.},$$

or the ore ran $\frac{1}{10}$ oz. Troy per ton.

"If 100 A. T. had been taken and the same weight bead obtained, we would have:

$$100 \text{ A. T.} : 1 \text{ A. T.} :: 50 \text{ mgrm.} : \tfrac{1}{2} \text{ mgrm.},$$

or the ore would run $\frac{1}{2}$ oz. Troy per ton.

"As an example of the calculation required without the large assay ton weights, I give the following:—

"Weight of panful of ore, $2\frac{1}{4}$ kilo. = 2,250,000 mgrm.

"Weight of bead obtained, gold 20 mgrm., silver 50 mgrm.,

$$\text{then } \frac{2{,}250{,}000 \text{ mgrm.}}{20 \text{ mgrm}} :: \frac{29166}{x} \times = \tfrac{25}{100} = \tfrac{1}{4} \text{ oz. gold}$$

$$\text{and } \frac{2{,}250{,}000 \text{ mgrm.}}{50 \text{ mgrm.}} :: \frac{29166}{x} \times = \tfrac{64}{100} = \tfrac{2}{3} \text{ oz. silver.}$$

Auriferous Mineral—continued.

"The free gold can be separated from the sulphurets (if it be desired to determine how much of the gold is "free" and how much in "sulphurets") by washing in an amalgamated pan. Such a vessel may be simply made by bending a piece of thin silver-plated copper (about 6 in. by 12 in.) so as to form curved edges on three sides, the silvered sides in. The side not turned up is one of the narrow ends. A little mercury (free from gold and silver) will quickly amalgamate the interior, and if the ore is washed carefully over this, most of the free gold will become amalgamated and stick to the pan. A piece of chamois skin made into a rubber will push the gold, which can be seen as little specks of amalgam, to the open edge of the pan and into a crucible. The mercury can be driven from the gold by heat.

"No investigation has been made to determine if any silver is carried by the mercury to the assay from the pan, but if such be the fact, the result is still accurate for gold. If carefully performed, the results ought to be above the yield from a stamp-mill with amalgamated plates.

"A more common test than the above silver-plated amalgamated copper pan is, after having panned down, to drop a few globules of clean mercury into the pan and a little cyanide of potassium (to keep the mercury clean). Work up with a spatula till the mercury has taken up the free gold, then collect, and run off the mercury. Clean it and dissolve in nitric acid (for the gold only) or drive off the mercury in the muffle; weigh the residue of gold and silver, part, and weigh gold.

"The residue in the pan should then be assayed, and the gold and silver (actual weight) determined. Suppose

Original weight of ore	$2\frac{1}{4}$ kilo.
Gold and silver after retorting	35 mgrm.
Gold after parting	15 ,,
Hence silver	20 mgrm.
Gold in sulphurets	50 ,,
Silver ,, ...	90 ,,

"Then we have:

Free gold $\frac{19}{100}$ oz. per ton of original ore.
Silver in free gold $\frac{25}{100}$ oz. per ton of original ore.
Gold in sulphurets $\frac{64}{100}$ oz. per ton of original ore.
Silver in sulphurets $1\frac{16}{100}$ oz. per ton of original ore.
Total gold $\frac{83}{100}$ oz. per ton of original ore.
Total silver $1\frac{41}{100}$ oz. per ton of original ore.

"There is a certain loss in panning, hence the results are not analytically accurate, but are close indications of the practical result of the working of gold ores in a mill with copper plates."—(*Brown.*)

ASSAYING: *Auriferous Mineral. c.* (Attwood.)

In assaying the gold sand of the rivers, streams, and sea beaches of California, some difficulty is met with, as it contains a great amount of specular titanic iron, and is called "black sand" by the miners. Platinum and iridium are often found in the same sand. Following is a convenient method of testing these sands:—

Take 100 to 1000 gr. and attack with aqua regia in a flask; cool for about 30 minutes or more; dilute with water, and filter. If gold is present, it will now be held in solution in the filtrate. Remove the filter, and evaporate the filtrates to dryness; then add a little hydrochloric acid, and redissolve the dry salt in warm water; add to the solution so formed protosulphate of iron, which will throw down the gold in the form of a fine, dark precipitate. This precipitate is seldom pure, being mixed with oxides of iron, and must now be dried in the filter paper, and both burned over the lamp in a porcelain dish. Then mix the dried precipitate with three times its weight of lead; fuse, scorify, and cupel. In case platinum, iridium, &c., are found associated with the gold, an exact amount of pure silver should be added before cupellation, and the gold button will be found pure.

ASSAYING: *Auriferous Mineral. d.* (Darton.)

Small parts are chipped from all the sides of a mass of rock, amounting in all to about ½ oz. This is finely powdered in a steel mortar, and well mixed. About half of it is placed in a capacious test tube, and then partly filled with a solution made by dissolving 20 gr. of iodine and 30 gr. of iodide of potassium in about 1½ oz. water. The mixture thus formed is thoroughly agitated by shaking and warming; then, after all particles have subsided, dip a piece of pure white filter paper in it, allow it to remain for a moment, then let it drain, and dry it over the spirit lamp. It is then placed upon a piece of platina foil held in pincers, and this heated to redness over the flame; the paper is speedily consumed; and after heating further, to burn off all carbon, it is allowed to cool, and then examined. If at all purple, gold is present in the ore, and the relative amount may be approximately deduced, as much, fair, little, or none. This method takes but little time and is very trustworthy.

ASSAYING: *Auriferous Mineral. e.*

The following simple method for the detection of gold in quartz, pyrites, &c., is an adaptation of the well known amalgamation process, and serves to detect very minute traces of gold. Place the finely powdered and roasted mineral in a test tube; add water and a single drop of mercury; close the test tube with the thumb, and shake thoroughly and for some time. Decant the water, add more, and decant repeatedly, thus washing the drop of mercury until it

Auriferous Mineral—continued.
is perfectly clean. The drop of mercury contains any gold that may have been present. It is therefore placed in a small porcelain capsule, and heated until the mercury is volatilised and the residue of gold is left in the bottom of the capsule. This residue may be tested either by dissolving in aqua regia and obtaining the purple of Cassius with protochloride of tin, or by taking up with a fragment of moist filter paper, and then fusing to a globule on charcoal in the blowpipe flame.

ASSAYING: *Auriferous Mineral. f.*

The mechanical assay of auriferous sands or stamped ore, based on common pan-washing, is of the utmost practical value to the miner as a working test. It does not give all the gold in the rock, as shown by a careful fire assay, but what is of equal importance to the mine owner, mill man, and practical miner, it gives what he can reasonably expect to save in a good quartz mill. It is really milling on a small scale. It is generally very correct and reliable, if a quantity of material be sampled. The only operation which requires much skill is the washing, generally well understood by those who are most likely to avail themselves of the instruction. These rules apply equally to placer gravels. Take a quantity of the ore—the larger the better—and spall it into pieces of less size than an egg. Spread on a good floor and, with a shovel, mix very thoroughly; then shovel into three piles, placing one shovelful upon each in succession, until all is disposed of. Two of the piles may then be put into bags. The remaining pile is spread out on the floor, mixed as before, and shovelled in the same manner into three piles. This is repeated according to the quantity sampled, until the last pile does not contain more than 30 lb. of ore. As the quantity on the floor becomes smaller, the lumps must be broken finer until the last, when they should not exceed 1 in. in diameter. What remains is removed to an iron slab and, by the aid of an iron ring and hammer, reduced to the size of peas. The whole 30 lb. is then spread out, and after careful mixing, portions are lifted with a flat knife—taking up the fine dust with the larger fragments—until about 10 lb. have been gathered. This quantity is then ground down fine with the muller, and passed through a 40-mesh sieve. If the rock is rich, the last portion will be found to contain some free gold in flattened discs, which will not pass the sieve. These must be placed with the pulverised ore, and the whole thoroughly mixed, if the quantity is small; but if large, must be treated separately, and the amount of gold calculated into the whole 10 lb., and noted when the final calculation is made. From the thoroughly mixed sample, 2 kilo. (2000 grammes) must be carefully weighed out. This is placed in a pan, or, better, in a batea, and carefully washed down until the gold begins to appear. Clean water is then used, and when the pan and the small residue are

Auriferous Mineral—continued.

clean, most of the water is poured off and a globule of pure mercury (which must be free from gold) is dropped in—a piece of cyanide of potassium is also placed with it. As the cyanide begins to dissolve, a rotary motion is imparted to the dish—best done by holding the arms stiff and moving the body. As the mercury rolls over and ploughs through the sand, under the influence of the cyanide, it will collect together all the particles of free gold. When it is certain that all is collected, the mercury may be carefully transferred to a small porcelain cup or test tube, and boiled with strong nitric acid, which must be pure. When the mercury is all dissolved, the acid is poured off, more nitric acid is applied cold, and rejected, and the gold is then washed with distilled water and dried. The object of washing with acid the second time is to remove any nitrate of mercury which might remain with the gold, and which is immediately precipitated if water is first used. The resulting gold is not pure, but has the composition of the natural alloy. Before accurate value calculations can be made, it will be necessary to render the gold pure and weigh it carefully. To purify the gold, it must be melted with silver, rolled out, or hammered thin, boiled twice with nitric acid, washed, dried, and heated to redness. The method of calculating this assay is very simple. It will be observed that 2000 grammes were weighed out. Let the 2000 grammes represent a ton of 2000 lb., then each gramme will be equivalent to 1 lb. avoirdupois, or one 2000th part of the whole, and the decimals of a gramme the decimals of a pound. Suppose the ore yielded, by the assay just described, fine gold weighing ·072 gramme, it must be quite evident that a ton of the ore would yield the same decimal of 1 lb. Now it is only necessary to multiply the value by the weight of gold obtained in grammes and decimals to find the value of the gold in a ton of ore. Care must be taken in this assay to keep the cyanide solution rather weak, as gold is somewhat soluble in strong solution of cyanide of potassium, and to remember that cyanide is deadly poison, which should be handled with great care.

ASSAYING: *Auriferous Mineral.* *g.*

Take (1) 200 gr. ore, 500 gr. litharge, 6 gr. lampblack, 500 gr. carbonate of soda; or (2) 200 gr. ore, 200 gr. red lead, 150 gr. carbonate of soda, 8 gr. charcoal, 6 gr. borax; mix and put into a warmed crucible, and cover with ½in. of common salt; fuse in a hot fire 30 minutes; cool, and break the pot; clean the button with a small hammer. If the quartz is very pyritous, take 1000 gr. and calcine "dead" without clotting. Add 500 gr. red lead, 35 gr. charcoal, 400 gr. borax, 400 gr. carbonate of soda. Cover with salt and proceed as above. In each case cupel the button. As the bone ash of which the cupel is made can absorb its own weight of metallic oxides, the cupel chosen should always exceed the weight

Auriferous Mineral—continued.

of the button to be operated on, so as to have a margin. Boil the gold prill, obtained from cupelling, in nitric acid, which dissolves the silver and leaves the gold pure. These formulæ are open to modification by the operator according to the apparent richness or poverty of the ore to be treated, and the presence and character of the basic impurities. In case there are oxides, a reducing agent is required; if sulphides, an oxidising agent. As a rule, employ a weight of litharge *twice* that of the ore, and of carbonate of soda the *same* as the ore. These reagents are added to control the size of the lead button, and to obtain one of a suitable size for cupelling. *See also p.* 345.

ASSAYING: *Auriferous Metal.*

Select from the samples several pieces, to represent as fair an average as possible, and divide each of them with the cold-chisel. Then with each piece, using the fresh cut edges, make parallel marks on a touchstone, and lay the pieces of gold on the table in the same succession. Wet the gold streaks on the stone with nitric acid, using a glass rod or the stopper of a coin test. If no reaction takes place, and the streaks look as bright and metallic as before, the gold is at least 640 fine, and probably finer even than that; wipe the stone gently with a piece of soft rag, and apply test acid in the same manner; if there is still no reaction, the gold is finer than 750; if any action is observed, the fineness is between the two. Test acid is made by mixing 98 parts of pure nitric acid of 37° Beaumé with two parts of hydrochloric acid of 21° B., and 25 parts of distilled water by measure. If the golden streaks are not acted on by nitric acid, or by the test acid, take a touch needle marked 700, and make a similar streak on the stone below that made with the samples. Compare the colour, and then progress with other needles, both copper and silver, using a higher mark each time, until a colour corresponds to that of the samples; an approximate knowledge of the quality of the gold will thus be obtained. But, should nitric acid cause any change in the appearance of the streaks on the touchstone, and the preliminary test in the watch glass indicated copper, try the copper needles and apply in the reverse order until you hit the colour, and find a needle, the streak of which is acted upon in a similar manner by nitric acid. If silver was indicated, use the silver needles. Considerable practice and a good eye are required to obtain accurate results with the touchstone, but this is soon acquired. Gold dust and retorted amalgam should be examined for mercury. This is done by putting a small fragment into a glass tube, closed at one end, observing that it falls quite to the bottom. Place the end of the finger loosely over the opening, and heat the closed end of the tube where the piece of gold lies, in the flame of the spirit lamp. If mercury is present, a bright ring will form in the tube above the

Auriferous Metal—continued.
assay. Upon examination with a magnifying glass, the ring will be found to be minute globules of mercury. To be certain, make a scratch with a file below the ring, and break off the closed end of the tube. Place the end of the now open tube into a few drops of water in a watch glass, and then, with a feather, or small stick, the sublimate may be brushed into the water, and by gently shaking, be caused to coalesce into a single globule, in which form it cannot be mistaken for any other substance.

ASSAYING : *Bullion.*

Any person skilled in the use of the blowpipe and possessing a good balance can make accurate assays of bullion or gold dust; but the results will be only approximate unless the whole lot is melted into a bar. As this is not always convenient, the following plan may be adopted. Pour the gold dust out on a large and perfectly clean sheet of paper, and with the ends of the fingers mix it thoroughly, occasionally lifting the edge of the paper to throw it together, and again mixing to ensure uniformity; then, from various parts, lift small portions, until more than 1 oz. is collected—this is best done with a flat knife, or by pinching with the thumb and forefinger—from this, weigh out accurately 1 oz. troy; place this in a small crucible, add a little borax, carbonate of soda, and nitrate of potash, and melt the whole together—this may easily be done in a blacksmiths' forge or in a coal stove; when perfectly melted, set the crucible aside, and when cold, break and remove the gold button; this must be freed from clay and slag by light blows of the hammer on its edges, and subsequent washing. When perfectly clean and dry, weigh again. The loss is water, iron, sand, mercury, and other impurities, which may be assumed to be the average of the entire lot. Cut off a small portion from each side with a cold-chisel, wrap the pieces in paper to prevent them from flying, and hammer down on the anvil until thin enough to cut with scissors; place upon charcoal, and heat with the blowpipe flame until the paper is burned away, taking care not to melt the gold. Cut with a pair of shears sufficient to weigh exactly $\frac{1}{10}$ gramme, or 100 milligrammes; a portion should be taken from each of the pieces. The weighing must be conducted with the greatest accuracy, for the success of the assay depends upon precise manipulation. Blowpipe cupels are made of the finest washed bone-ash, formed in a cupel mould of boxwood or ebony, hammered with sufficient force to make them compact, and well dried. They are about $\frac{1}{4}$ in. diameter, and less than that in height. For convenience, they may be supported in a ring of platinum wire, in a handle of cork, or fused into a glass rod. Place the assay in the centre of a piece of lead foil about $\frac{1}{2}$ in. square; fold the lead over the gold, and with the fingers carefully form it into a ball and set it aside.

Bullion—continued.

Prepare two assays like this. Take the cupel support in the left hand, and, having lighted a spirit lamp, lift one of the cupels by placing the end of the forefinger in the concave part, and holding it lightly with the thumb, place it in the loop of wire. Heat the cupel by urging the whole of the flame upon it, producing in doing so a roaring sound. This is best done by holding the point of the blowpipe outside the flame. When the cupel is hot enough, which is known by its becoming white after first blackening, lift with the pliers one of the assays, and place it in the centre of the cupel. A steadily-pointed blue flame must then be directed upon the assay until it melts and begins to oxidise, when the flame is changed to a roaring blast, and the cupel is moved farther from the lamp. Cupellation goes on rapidly if the flame is directed against the cupel beyond the assay, and not directly upon it, and if the cupel is kept cool—that is to say, at the lowest temperature at which the lead can be kept fluid. It will be found advantageous to discontinue the flame for an instant occasionally, and to direct it by short puffs at times. The exact point can only be attained by removing the cupel from the lamp, and returning it gradually, as may be required. As the cupellation goes on, the bead becomes more spherical; little patches of lead oxide form and pass to the cupel, becoming thinner, until at last the gold bead can be seen through the slight film of oxide. When nearly finished, the molten gold spits up towards the flame. At last, at the proper moment, learned only by practice, an instant cessation of the blast causes a flash, and a bright yellow golden bead remains on the cupel. When cold, the bead is removed from the cupel with pliers, and placed flat side down on a clean piece of paper. It is then grasped with a large pair of pincers and squeezed by a strong pressure. This generally removes all adhering bone-ash, and renders the button fit for weighing. To make sure, turn it over, examine with the magnifying glass, and brush with a small short-bristle brush. If anything should be found attached to it, a squeeze at right angles with the first will generally remove it. Place the button in the pan of the balance and weigh it carefully. Its weight in milligrammes is the total fineness in hundredths. For instance, 74 milligrammes would be 740 fine. With a delicate balance, thousandths can be weighed, each tenth of a milligramme being ·001.

The button will probably contain silver. To ascertain the fineness of gold, it must be subjected to a second process. The weight of the bead being noted, a cavity is made in a piece of charcoal, held by means of a proper support. In the cavity is placed the gold button, with four or five times its volume of pure silver, and both metals are melted together before a strong blowpipe flame. The alloy must be thoroughly fused. When cool, it is wrapped in paper, hammered flat, heated red hot to burn away the paper, cleaned with the stiff brush, placed in a test tube with nitric acid,

Bullion—continued.

and boiled over a spirit lamp until no more red fumes are given off. A black powder, which is the gold, will remain. The tube is then filled up with distilled water, which is poured off carefully, so as not to permit any of the finely divided gold to pass away with it. This must be repeated, and the tube filled full for the third time with distilled water. A porcelain cup is then placed over the tube, like a cap, and both are inverted together. The gold falls to the bottom of the cup, and the tube is carefully removed. The water is then poured from the gold in the cup, which is first subjected to a gentle heat, and then made red-hot by the aid of the blow-pipe. During the process the cup may be held, by the aid of pincers, over the flame of the spirit lamp, which is urged upward against it from below. When the gold has assumed its metallic colour, the operation is finished. When cold, the gold is brushed into the pan of the balance, and its weight in tenths of a milligramme is noted. The results may be written as follows: Suppose the weight of the cupelled button, in milligrammes, to be 74·4, the total fineness will be 744; weight of gold powder, 69·2 = 692; fineness of silver, 52. Or, fineness of gold, 692; fineness of silver, 52; total fineness, 744.

It is important in estimating the value of purchased gold dust, to carefully examine, to see if there is any counterfeit, or, as it is called, "bogus" dust present. If all from the same locality, the dust will have a uniform colour. Any suspicious-looking pieces should be set aside and cut with a cold chisel while lying on a small anvil. A fair sample of the whole lot of gold dust under examination should then be placed in an evaporating dish, the suspected pieces being placed on top, and nitric acid poured over them. If any reaction takes place, such as effervescence, or evolution of red fumes, or if the acid becomes coloured, there is foreign matter present, and should this be the case, adulteration or counterfeit gold dust may be suspected. Place two watch glasses, one on a piece of white paper and the other on black, or some dark colour; then, with a glass rod, convey a few drops of the acid from the dish to each. To the white add a drop or two of ammonia until it smells strongly ammoniacal; a blue colour indicates copper. To the other add hydrochloric acid in the same manner. If a white, curdy precipitate forms, which does not dissolve upon the addition of water, silver is being dissolved from the gold dust in the evaporating dish. If the dust is of very low grade, these metals may dissolve in very small quantities. But such gold dust would be easily detected by its inferior colour and appearance. If no action is observed, even after heating the dish, there is no counterfeit present. Counterfeit gold dust is sometimes heavily coated with pure gold (by the galvanic process) so as to protect the base alloy from the action of nitric acid, hence the necessity of cutting all suspected pieces before submitting to the action of the acid. To remove the acid from the gold, wash with water thoroughly, and dry over the spirit lamp.

Table 137.—*Sulphurets, identifying.* (Brown.)

Kind of Sulphuret.	Before Heating.		During Rapid Heating.			After Heating (when cold).		
			Fumes.					
	Colour of Ore.	Character.	Character.	Odour.	Other Characteristics.	Colour of Ore.	Character.	Composition.
1. Blende	Brown, shading to green, red, and yellow	Shining	Very slight	None	Glows yellow-green when hot	Buff or yellowish	Dead, dull	Oxide of zinc.
2. Manganblende .	Green, greenish grey	Dull	Slight	None	Glows	Brown	Dead, dull	Brown oxide of manganese.
3. Pyrite	Greenish or brownish black	Shining, not magnetic	Slight	None	Glows	Red to black, many shades	Dead, dull	Red oxide of iron.
4. Pyrrhotite ..	Grey black	Shining, is magnetic	Slight	None	Glows	Red to black, many shades	Dead, dull	Red oxide of iron.
5. Arsenopyrite ..	Grey black	Shining	White, very thick	Like garlic	Glows, swells	Red to black, many shades	Dead, dull	Red oxide of iron.
6. Chalcocite ..	Grey	Shining	Slight	None	Glows, fuses	Grey	Shining, powder red	Oxide of copper.
7. Chalcopyrite ..	Green black	Shining	Some fumes	None	Glows, fuses	Grey	Shining, powder grey	Oxides of iron and copper.
8. Bornite	Dark green	Shining	Some fumes	None	Glows	Grey	Shining, powder brown,	Oxides of iron and copper.
9. Tetrahedrite ..	Dark grey	Shining	Much	Garlic odour sometimes	Glows, swells, fuses	Grey	Shining	Mixed oxides.
10. Stibnite	Lead grey	Shining	White fumes	None	Swells, melts, boils	Grey green	A thin film of shining mass	Oxide of antimony.
11. Galenite	Grey	Very decided shine	Fumes considerably	None	Fuses	Yellow green	Shining	Oxide of lead.
12. Argentite.. ..	Grey black, pink and brown shades	Very little shine	Some	None	Fuses	Grey	Somewhat shining	Oxide of silver somewhat reduced.

(Each sulphuret will give a little odour of sulphur, but it is not to be confounded with the odour of arsenic.)

Table 138.—*Reducing Agents.*

1 part of the undermentioned will reduce of metallic lead:—

	Parts.		Parts.
Argol, crude ..	5½–8½	Flour, wheat	15
Charcoal, ordinary	22–30	Gum arabic, powdered	11
Coke, powdered ..	24	Starch, corn	11½–13
hard coal	25	„ laundry	11½–13
soft „	22	Sugar, white, powdered	14½
Cream of tartar			

Table 139.—*Sulphurets, oxidising.* (Brown.)

Kind of Sulphuret.	Parts of litharge required to completely oxidise 1 part of the sulphuret.	Parts of metallic lead reduced by 1 part of the sulphuret.	Percentage of the sulphuret which with charges of 1 A.T. will reduce a lead button of about 15 grm.	Parts of nitre required to completely oxidise 1 part of the sulphuret.
1. Zinc blende	25	6·5	7·7	—
2. Manganblende	30	6·7	7·5	—
3. Iron pyrites	50	8·6	5·8	2·5
4. Arsenopyrite	40	7·3	6·5	—
5. Copper pyrites	30	7·2	7	—
6. Copper glance	25	3·8	13	—
7. Grey copper	35	6	8	—
8. Grey antimony	25	5·7	9	—
9. Galena	1·8	2·8*	18	·66

* All the lead of the galena and litharge.

Table 140.—*Charges for Gold and Silver Ores.*

Ingredients.	Assay tons.	Grammes.	Troy gr.
1. Antimonial and arsenical ores. (Brown.)			
Ore	1/6	5	96
Granulated lead	4	120	1920
Borax glass	—	1½	23
2. Carbonate ores. (Brown.)			
Ore	1/6	5	96
Granulated lead	2	60	960
Borax glass	—	½	7½
3. Chloride ores. (Brown.)			
Ore	1/6	5	96
Granulated lead	1 1/5	33	576
Borax glass	—	⅓	5
4. Common ores not containing much lead or copper. (Brown.)			
Ore	1/10	2½	48
Granulated lead	2½	75	1200
Borax glass	—	¼	4
5. Common ores. (Mitchell.)			
Ore	1	30	480
Soda	1	30	480
Litharge	5	150	2400
Borax glass	1	30	480
Salt cover.			
6. Common ores. (Brown.)			
Ore	1	30	480
Soda	1	30	480
Litharge	1·65	50	800
Salt cover.			
7. Common ores. (Aaron.)			
Ore	1	30	480
Soda	3	90	1440
Litharge	1	30	480
Borax	½	15	240
Sulphur	1/10	3	48
Flour	1/10	3	48
Iron, 3 nails.			
Glass.			
Salt cover.			
8. Common ores, not pyritic. (Aaron.)			
Ore	1	30	480
Soda	1	30	480
Litharge	2	60	960
Borax, dried	1	30	480
Flour	—	1	16
Salt cover.			

Table 140—*continued.*

Ingredients.	Assay tons.	Grammes.	Troy gr.
9. Common ores, not pyritic. (Brown.)			
Ore	1	30	480
Soda bicarbonate	1½	45	720
Potash carbonate	½	15	240
Litharge	1½	45	720
Silica	1	30	480
Borax glass	½	15	240
Charcoal	—	⅗	9¼
Salt cover; ¼ hour in fire.			
10. Copper glance or pyrites. (Brown.)			
Ore	1/10	2½	48
Granulated lead	2½	75	1200
Borax glass	—	⅕	3
11. Copper matte. (Brown.)			
Matte	1/10	2½	48
Granulated lead	3	90	1440
Powdered silica	1/20	1½	24
12. Copper, grey ores. (Brown.)			
Ore	1/10	2½	48
Granulated lead	2	60	960
Borax glass	—	⅓	5
13. Iron sulphides. (Brown.)			
Ore	¼	7½	120
Granulated lead	2½	75	1200
Borax glass	—	⅙	3
14. Iron oxides. (Brown.)			
Ore	⅙	5	96
Granulated lead	1½	45	720
Silica	—	1	15½
Borax glass	—	⅓	5½
15. Lead sulphide. (Brown.)			
Ore	½	15	240
Granulated lead	1½	45	720
Borax glass	—	1/10	1½
16. Native gold or silver, or *very* rich ores. (Brown.)			
Ore	1/10	2½	48
Granulated lead	1½	45	720
Borax glass	—	¼	4
17. Tellurides. (Brown.)			
Ore	1/10	2½	48
Granulated lead	2	60	960
Litharge	1/10	2½	48
Borax glass	—	¼	4
18. Zinc blende. (Brown.)			
Ore	⅙	5	96
Granulated lead	3	90	1440
Borax glass	—	⅜	6

Table 141.—*Assay Ton Equivalents in Grammes, Troy Grains, and Troy Ounces.* (Brown.)

Based on 1 grm. = 15·43235 Troy gr.; hence 1 assay ton or 29·166 grm. = 15·43235 × 29·166 = 450·09992 Troy gr.

A. T.	Grm.	Troy gr.	Troy oz.	A. T.	Grm.	Troy gr.	Troy oz.
0·05	1·458	22·504	..	2·50	72·916	1125·249	2·344
0·10	2·916	45·009	..	2·55	74·374	1147·754	2·391
0·15	4·374	67·514	..	2·60	75·833	1170·259	2·438
0·20	5·833	90·019	..	2·65	77·291	1192·764	2·485
0·25	7·291	112·524	..	2·70	78·749	1215·269	2·531
0·30	8·749	135·029	..	2·75	80·208	1237·774	2·579
0·35	10·208	157·534	..	2·80	81·666	1260·279	2·626
0·40	11·666	180·039	..	2·85	83·124	1282·784	2·672
0·45	13·124	202·544	..	2·90	84·583	1305·289	2·719
0·50	14·583	225·049	..	2·95	86·041	1327·794	2·766
0·55	16·041	247·554	..	3·00	87·499	1350·299	2·813
0·60	17·499	270·059	..	3·05	88·958	1372·804	2·860
0·65	18·958	292·564	..	3·10	90·416	1395·309	2·905
0·70	20·416	315·069	..	3·15	91·874	1417·814	2·954
0·75	21·874	337·574	..	3·20	93·333	1440·319	3·001
0·80	23·333	360·079	..	3·25	94·791	1462·824	3·048
0·85	24·791	382·584	..	3·30	96·249	1485·329	3·094
0·90	26·249	405·089	..	3·35	97·708	1507·834	3·141
0·95	27·708	427·594	..	3·40	99·166	1530·339	3·188
1·00	29·166	450·099	..	3·45	100·624	1552·844	3·235
1·05	30·624	472·604	..	3·50	102·083	1575·349	3·282
1·10	32·083	495·109	1·032	3·55	103·541	1597·854	3·329
1·15	33·541	517·614	1·078	3·60	104·999	1620·359	3·376
1·20	34·999	540·119	1·125	3·65	106·458	1642·864	3·423
1·25	36·458	562·624	1·173	3·70	107·916	1665·369	3·470
1·30	37·916	585·129	1·219	3·75	109·374	1687·874	3·516
1·35	39·374	607·634	1·266	3·80	110·833	1710·379	3·563
1·40	40·833	630·139	1·313	3·85	112·291	1732·884	3·610
1·45	42·291	652·644	1·360	3·90	113·749	1755·389	3·657
1·50	43·749	675·149	1·407	3·95	115·208	1777·894	3·704
1·55	45·208	697·654	1·453	4·00	116·666	1800·399	3·751
1·60	46·666	720·159	1·500	4·05	118·124	1822·904	3·798
1·65	48·124	742·664	1·547	4·10	119·583	1845·409	3·845
1·70	49·583	765·169	1·594	4·15	121·041	1867·914	3·891
1·75	51·041	787·674	1·641	4·20	122·499	1890·419	3·938
1·80	52·499	810·179	1·667	4·25	123·958	1912·924	3·985
1·85	53·958	832·684	1·735	4·30	125·416	1935·429	4·032
1·90	55·416	855·189	1·782	4·35	126·874	1957·934	4·079
1·95	56·874	877·694	1·829	4·40	128·333	1980·439	4·126
2·00	58·333	900·199	1·875	4·45	129·791	2002·944	4·173
2·05	59·791	922·704	1·922	4·50	131·249	2025·449	4·220
2·10	61·249	945·209	1·969	4·55	132·708	2047·954	4·267
2·15	62·708	967·714	2·016	4·60	134·166	2070·459	4·313
2·20	64·166	990·219	2·063	4·65	135·624	2092·964	4·360
2·25	65·624	1012·724	2·110	4·70	137·083	2115·469	4·407
2·30	67·083	1035·229	2·157	4·75	138·541	2137·974	4·454
2·35	68·541	1057·734	2·204	4·80	139·999	2160·479	4·500
2·40	69·999	1080·239	2·250	4·85	141·458	2182·984	4·548
2·45	71·458	1102·744	2·297	4·90	142·916	2205·489	4·595

Table 141—*continued.*

A.T.	Grm.	Troy gr.	Troy oz.	A.T.	Grm.	Troy gr.	Troy oz.
4·95	144·374	2227·994	4·642	7·50	218·749	3375·729	7·033
5·00	145·833	2250·499	4·689	7·55	220·208	3398·234	7·080
5·05	147·291	2273·004	4·735	7·60	221·666	3420·739	7·127
5·10	148·749	2295·509	4·782	7·65	223·124	3443·244	7·173
5·15	150·208	2318·014	4·829	7·70	224·583	3465·749	7·220
5·20	151·666	2340·519	4·876	7·75	226·041	3488·254	7·267
5·25	153·124	2363·024	4·923	7·80	227·499	3510·759	7·314
5·30	154·583	2385·529	4·970	7·85	228·958	3533·264	7·361
5·35	156·041	2408·034	5·017	7·90	230·416	3555·769	7·408
5·40	157·499	2430·539	5·064	7·95	231·874	3578·274	7·455
5·45	158·958	2453·044	5·111	8·00	233·333	3600·779	7·502
5·50	160·416	2475·549	5·157	8·05	234·791	3623·284	7·549
5·55	161·874	2498·054	5·204	8·10	236·249	3645·789	7·595
5·60	163·333	2520·559	5·251	8·15	237·708	3668·294	7·642
5·65	164·791	2543·064	5·298	8·20	239·166	3690·799	7·689
5·70	166·249	2565·569	5·345	8·25	240·624	3713·304	7·736
5·75	167·708	2588·074	5·392	8·30	242·083	3735·809	7·783
5·80	169·166	2610·579	5·439	8·35	243·541	3758·314	7·830
5·85	170·624	2633·084	5·486	8·40	244·999	3780·819	7·877
5·90	172·083	2655·589	5·532	8·45	246·458	3803·324	7·924
5·95	173·541	2678·094	5·579	8·50	247·916	3825·829	7·970
6·00	174·999	2700·579	5·626	8·55	249·374	3848·334	8·017
6·05	176·458	2723·084	5·673	8·60	250·833	3870·839	8·064
6·10	177·916	2745·589	5·720	8·65	252·291	3893·344	8·111
6·15	179·374	2768·094	5·767	8·70	253·749	3915·849	8·158
6·20	180·833	2790·599	5·814	8·75	255·208	3938·354	8·205
6·25	182·291	2813·104	5·861	8·80	256·666	3960·859	8·252
6·30	183·749	2835·609	5·908	8·85	258·124	3983·364	8·299
6·35	185·208	2858·114	5·954	8·90	259·583	4005·869	8·346
6·40	186·666	2880·619	6·001	8·95	261·041	4028·374	8·392
6·45	188·124	2903·124	6·048	9·00	262·449	4050·879	8·439
6·50	189·583	2925·629	6·095	9·05	263·958	4073·384	8·486
6·55	191·041	2948·134	6·142	9·10	265·416	4095·889	8·533
6·60	192·499	2970·639	6·189	9·15	266·874	4118·394	8·580
6·65	193·958	2993·144	6·236	9·20	268·333	4140·899	8·627
6·70	195·416	3015·649	6·283	9·25	269·791	4163·404	8·674
6·75	196·874	3038·154	6·329	9·30	271·249	4185·909	8·721
6·80	198·333	3060·659	6·376	9·35	272·708	4208·414	8·768
6·85	199·791	3083·164	6·423	9·40	274·166	4230·919	8·814
6·90	201·249	3105·669	6·470	9·45	275·624	4253·424	8·861
6·95	202·708	3128·174	6·517	9·50	277·083	4275·929	8·908
7·00	204·166	3150·679	6·564	9·55	278·541	4298·434	8·955
7·05	205·624	3173·184	6·611	9·60	279·999	4320·939	9·002
7·10	207·083	3195·689	6·658	9·65	281·458	4343·444	9·049
7·15	208·541	3218·194	6·705	9·70	282·916	4365·949	9·096
7·20	209·999	3240·699	6·751	9·75	284·374	4388·454	9·143
7·25	211·458	3263·204	6·798	9·80	285·833	4410·959	9·189
7·30	212·916	3285·709	6·845	9·85	287·291	4433·464	9·236
7·35	214·374	3308·214	6·892	9·90	288·749	4455·969	9·283
7·40	215·833	3330·719	6·939	9·95	290·208	4478·474	9·330
7·45	217·291	3353·224	6·986	10·00	291·666	4500·979	9·377

By using this system, calculation of gold and silver values of an ore becomes very simple.

Assay Ton equivalents—continued.

Ex. 1.—Amount of ore taken	$\frac{1}{5}$ A. T.
Amount of test-lead used	$1\frac{1}{2}$ „
	MGRM.
Weight of gold and silver bead	8·50
„ silver in $1\frac{1}{2}$ A. T. lead	·25
True weight of gold and silver bead ..	8·25
Weight of gold in the bead	1·10
Weight of silver in the bead	7·15

$7·15 \times 5 = 35·75 = 35\frac{3}{4}$ mgrm. $= 35\frac{3}{4}$ oz. silver per ton of ore.
$1·10 \times 5 = 5·5 = 5\frac{1}{2}$ mgrm. $= 5\frac{1}{2}$ oz. gold per ton of ore.

Ex. 2.—Amount of ore taken	$\frac{1}{2}$ A. T.
Amount of test-lead used	1 „
	MGRM.
Weight of gold and silver bead	231·90
Weight of silver in test-lead	0·00
True weight of gold and silver bead	231·90
Weight of gold, "faint trace"	0·00
Weight of silver in the bead	231·90

$231·9 \times 2 = 463·8 = 463\frac{8}{10}$ mgrm. $= 463\frac{8}{10}$ oz. silver per ton of ore. · (Brown.)

Copper.

(*a*) *Native Ore.*—Into a crucible put—

	Grammes.	Troy gr.
Ore	10	160
Soda bicarbonate	20	320
Potash carbonate	5	80
Borax glass	1	16

Cover with $\frac{1}{2}$-in. salt and 1 in. wood charcoal; heat intensely for 20–30 minutes; cool, break crucible, clean button from slag; divide weight of button by 10 grm. or 160 gr. and multiply by 100 for percentage of copper.

(*b*) *Oxides and Carbonates, free from sulphur.*—Into a chalk-lined crucible put—

	Grammes.	Troy gr.
Ore	10	160
Black flux substitute (10 parts soda bicarbonate, 3 wheat flour)..	30	480
Borax glass	5	80
Argol	2	32

Cover with salt and charcoal as (*a*); heat gradually 20 minutes, and to white heat for 40; remove, tap, and cool.

Copper—continued.

(*c*) *Sulphides, containing antimony, arsenic, lead, mercury, zinc, &c.*—In order to concentrate all the copper into a matte, and eliminate lime or baryta gangues, mix—

	Grammes.	Troy gr.
Ore, according to richness	10–30	160–480
Borax glass	8–24	128–384

Add a couple of nails if lead is present; also 2–6 grm. (32–96 gr.) iron pyrites free from copper, unless present in the ore to some extent. Use a salt cover; fuse in hot fire; remove nails when finished, cool, break away slag.

Next roast the matte with extreme care, using coke and no silica, so as to expel sulphur and volatile metals, and convert copper into an oxide.

To reduce the oxide to metal, mix—

	Grammes.	Troy gr.
Roasted ore	30	480
Black flux substitute (10 parts soda bicarbonate, 3 wheat flour)..	90	1440
Borax glass	15	240
Lime glass	$7\frac{1}{2}$	120
Red oxide of iron	3	48

introducing first into the crucible a mixture of the ore, iron oxide, and one-third the black flux substitute; when settled down, add the rest of the black flux substitute, borax glass, lime glass, and salt cover successively, laying on all a piece of coal, the size of a hazel nut. Gradually raise heat to intensity; remove, cool, detach button, weigh and estimate if malleable and apparently pure.

If not pure, heat two large cupels in a muffle; place in each 3 grm. (48 gr.) pure lead, and close muffle; when lead is melted, put the impure button (*a*) in one cupel and a piece of pure copper (*b*) of same weight in the other. On their "brightening," cover cupels with coke or coal-dust, take out and cool in water. Add loss sustained by *b* to both, and compare.

(*d*) *All Ores, or Alloys.*—This is an electrolytic (wet) process, preferable to all the others. Place 1 grm. of rich ore (over 20 per cent.) or 5 grm. of poor (under 20 per cent.), very finely ground, in a casserole, cover with watch-glass, and add 10 c.c. pure concentrated nitric acid from a pipette. Heat in sand bath for some time; when cold add 5 c.c. pure concentrated sulphuric acid, and boil till red fumes give way to white. When cold again, add 50 c.c. distilled water, stir, warm, and put by to settle. Filter off the clear solution, which should contain all the copper. Collect the filtrate in a clean glass beaker, and place in the beaker a perfectly clean and previously dried and weighed platinum dish or piece of foil. Connect with a two-cell Bunsen or Daniell battery, coupled for intensity. In about 10–12 hours, the electric current will have decomposed the solution, and caused a deposition of metallic copper on the platinum foil. This need only be dried and weighed.

Lead.

(*a*) *Sulphides.*—Mix—

	Grammes.	Troy gr.
Ore	10	160
Potash cyanide	30	480

cover with salt in crucible, fuse for ¼-hour; the lead comes out as a clean malleable button. Avoid unnecessary heat.

(*b*) *Carbonates and Oxides.*—Fuse—

	Grammes.	Troy gr.
Ore	10	160
Soda bicarbonate	15	240
Potash carbonate	5	80
Argol	5	80

under a salt cover, in a crucible, without lid if in muffle, heating gradually for first ½-hour. Cool under lid, or pour.

Tin.

(*a*) Pack 5 grm. potash cyanide into the bottom of a crucible; then charge with 10 grm. ore mixed with 40 grm. cyanide; cover with 5 grm. cyanide, and fuse ¼-hour. The button comes out clean, bright, and free from iron; the impurities collect in the slag at the bottom of the crucible. The result is about ½ per cent. under that of chemical analysis. Associated minerals affect the result but little.

(*b*) Intimately mix and put in a clay crucible—

	Grammes.	Troy gr.
Ore	5	80
Charcoal dust	¾–1	12–16
Covering with black flux or substitute (2 parts potas-soda carb., 1 part flour)	12½–15	200–240
Borax glass	1–1¼	16–20

adding a salt cover and finally a piece of charcoal. Apply the lid, heat moderately at first and increase till boiling ceases, then at a white heat for ½–¾-hour. Cool and break. The button comes out almost as well as in (*a*) and the result is nearly as accurate, while the cost is much less.

(*c*) *Separation of Tin and Antimony.*—(1) The powdered ore or slag is introduced into a nickel crucible and intimately mixed with about 10 times its weight of a mixture of sodium carbonate and 1 of borax, the decomposition being brought about by the application for a few minutes of a full red heat from an ordinary foot blow-pipe. When all necessary reaction has terminated, the contents may be poured on an iron slab. The melt thus obtained is readily and completely discoloured by a little dilute HCl, introduced into a flask of known capacity, together with the small quantity which still adheres to the sides of the crucible, which is readily detached by pouring in a further quantity of dilute acid and gently warming. The contents of the flask are diluted to the containing mark, and a

Tin—continued.
known quantity is withdrawn by a pipette, which is received into an accompanying flask, and saturated with a stream of SH_2 gas. Tin, antimony, and similar metals of the same group, are precipitated as sulphides; the mixed precipitates are filtered and collected by a plug of cotton inserted in the neck of a glass funnel. The cotton with its contents after being once washed is dislodged and received into a vessel containing a strong solution of NaHO, raised to and maintained for a few minutes at boiling point, the tin and antimony sulphide passing into solution as sulphostannate and sulphoantimoniate of soda.

The soluble tin and antimony compounds thus obtained are separated by refiltering as in the previous filtration, and divided into two separate portions, being received for convenience sake into two flasks, and labelled A and B portions; to the A portion is introduced a somewhat large excess of oxalic acid, and the solution is allowed to boil until the small quantity of antimony sulphide that remains presents a pure orange-red precipitate, characteristic of that compound: the precipitate being collected in the usual manner and decomposed in a porcelain crucible at a very low red heat, weighing as Sb_2O_4 and calculating to percentage of antimony.

To the second, or B portion, is added an excess of dilute HCl, and the whole is gently warmed; the reprecipitated sulphide thus obtained is treated precisely the same as in the previous instance, weighing as oxides, the total percentage of tin being obtained by deducting the former weight of precipitated oxide obtained from the A portion from that of the mixed oxides obtainable from the second or B portion, and calculating by its respective formula.

The speed and accuracy obtainable largely depend upon the judicious use of the borax, whereby not only a most readily fusible compound is obtained, but at the same time readily soluble in acid. (H. N. Warren.)

(2) The sample must first be reduced to as fine a condition as possible and in the case of a type metal, this is easily accomplished by paring with a knife. A weighed quantity of the sample is taken, placed in a beaker, and treated several times with concentrated HNO_3, evaporating nearly to dryness after each treatment. By this operation the Sb and Sn are converted into insoluble oxides. Remove to a filter and wash well with boiling water. After repeated washing with the water, treat again with HNO_3, and evaporate to complete dryness. Ignite to destroy the filter paper, transfer to a silver crucible, and ignite the residue with about 8 times its weight of pure NaOH. This fusion is best accomplished on a sand bath. If a higher temperature be employed, there is a danger of losing some of the substance, owing to the "spitting" which will take place. The fusing must be continued until the mass is completely liquid. Allow to cool and treat with hot water in a beaker, to dissolve out the tin, add rather a large quantity of water, then alcohol to about a third of the bulk of water used, and

Tin—continued.
allow to stand for 24 hours, with frequent stirring. Filter and wash well with 1 vol. alcohol to 2 vols. water. Fuse the insoluble again with NaOH as before, and repeat the treatment with hot water and alcohol, allowing to stand again for 24 hours as before. Filter and wash repeatedly with equal bulks of alcohol and water. Add the filtrates together = *Filtrate No.* 1.

The insoluble portion is now treated with a saturated solution of tartaric acid, to which a few drops of HCl have been added. This dissolves out the Sb, leaving behind any other impurity which may be present. Dilute largely with water, and pass SH_2 gas, until the Sb is completely precipitated. Filter and dissolve precipitate in HNO_3, transfer to a porcelain crucible, and evaporate with fuming HNO_3. This evaporation, which must be repeated several times, drives off the free sulphur, destroys the filter paper, and oxidises the sulphide of antimony to Sb_2O_4. Dry and weigh, multiply the weight by ·7893. The result is the weight of metallic Sb in the quantity of the sample taken.

FILTRATE NO. 1.—This contains the whole of the tin in solution. Evaporate to about ¼ of its bulk; add a few drops of HCl, and pass SH_2 gas to precipitate the Sn as SnS_2. To obtain complete separation of the Sn, some care is necessary, the HCl must be but slightly in excess, and the solution must be kept hot to facilitate the formation of the sulphide. The best way to do this is to boil the liquid first, then saturate with the gas and boil again, repeating this process until the whole of the Sn is precipitated; filter, wash well with water, and ignite, allowing free access to the air. Weigh, and multiply by ·7866; the result equals the weight of metallic tin.

The great advantage of this method is the slight liability to loss, owing to the very insoluble nature of the precipitates. The manual dexterity required is not very great. The one chief drawback to the method is the length of time required to perform the entire operation, but this is amply compensated for by the accuracy of the results obtained. (*Chemical Trade Journal Prize Essays.*)

Auriferous Mineral. (*h.*) (A. F. Crosse.)
(Continued from p. 331.)

The following method is of great practical utility in determining the milling value of an auriferous ore, and at the same time indicating in outline the process likely to be best adapted for its treatment.

The mineral is prepared in the usual way so that it will pass through a 900-mesh sieve. One sample (A) is subjected to the ordinary fire assay in order to determine the *whole* amount of gold present. A duplicate sample (B) of, say, 1000 gr., is mixed with water, and shaken up for some time either in a well-closed copper vessel amalgamated inside, or in a wide-mouthed glass-stoppered bottle containing bits of amalgamated sheet copper, taking care

Auriferous Mineral—continued.
to avoid excess of mercury and any possibility of leakage. The residue (C) after continued shaking (when all free gold has become absorbed by the amalgamated surface) is poured into a filter, dried, and assayed. The difference between the fire assay of C and that of A will give the percentage of *free amalgamable* gold present in the ore.

The next step is to determine how much of the gold in the residue C is locked up in pyrites and how much is "float" gold. For this purpose a duplicate sample of the residue C is weighed into an elutriator, or sort of miniature *spitz-kasten*, being a conical vessel 7–8 in. high, with two holes, one near the bottom for admitting water, and a second at the bottom for letting out the water and ore after treatment. Water is furnished from a tap by means of a tin or rubber tube held in a clamp, the rate of flow being so adjusted that the level remains fairly constant. The stream being very slow and regular, it may be safely reckoned that all gold washed away by it would be similarly lost on any known form of concentrator.

The "float gold" (D) being thus washed away with the slimes, a fire assay of the concentrates (E) remaining in the elutriator will reveal by difference how much of the non-amalgamable gold is in pyrites and how much is float gold. Thus—

	Gold per ton. oz.	dwt.	gr.
Original sample A gave	1	1	0
Of this amount—			
Residue B gave	0	5	12
Therefore, amalgamable gold =	0	15	12
Of the $5\frac{1}{2}$ dwt., there were found in E which is presumably pyritous,	0	2	12
Leaving a balance of being float gold that escaped with the slimes.	0	3	0

Table 142.—*Alloys.*

	Aluminium.	Antimony.	Arsenic.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Platinum.	Silicium.	Silver.	Tin.	Zinc.
Acid proof (Reith)	..	1	..	..	..	15	..	..	1·82	..	..	..	..	..	2·34	..
Aich	..	..	..	..	..	60	..	1·8	..	..	..	..	..	..	..	38·2
Aluminium bronze	90	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..
„ brown	95	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..
Amalgams, Arrington	..	..	..	..	..	..	..	..	..	..	..	..	..	40	60	..
„ diamond	..	..	..	..	..	..	1·50	..	..	..	..	..	..	31·76	66·74	..
„ Hood's	..	..	..	..	..	..	2·70	2·90	..	..	..	..	..	34·64	60·37	..
„ Johnson & Lund's	..	..	..	..	..	..	0·81	..	..	..	..	1·34	..	38·27	59·58	..
„ Lawrence's	..	..	..	..	..	14·91	3·54	..	..	..	..	..	..	47·87	33·68	..
„ Moffitt's	..	..	..	..	..	..	2·82	..	..	..	..	..	..	35·17	62·01	..
„ Townsend's	..	..	..	..	..	10·65	1·6	..	..	..	..	..	..	40·21	47·54	..
„ „	..	..	..	..	..	..	5·31	..	..	..	..	..	..	39·00	55·65	..
„ Walker's	..	..	..	..	..	..	4·14	..	..	..	..	0·96	..	34·89	60·01	..
Argentan	..	..	..	..	..	55	..	..	..	..	21	..	..	..	..	24
Arguzoid	..	..	..	..	..	56	..	3·5	..	..	13·5	..	..	..	4	23
Babbitt	..	..	..	..	..	4	..	..	..	..	..	..	..	..	96	8
Bell	..	..	..	..	..	4	..	..	..	..	..	..	..	..	1	..
„	..	..	..	..	..	78	..	..	..	..	..	..	..	..	22	..
„ church	..	..	..	..	..	80	..	..	4·3	..	..	..	..	..	10·1	5·6
„ „	..	..	..	..	..	69	..	..	..	..	..	..	..	..	31	..
„ clock	..	..	..	..	..	72	..	1·5	..	..	..	..	..	..	26·5	..
„ „	..	..	..	..	..	87·5	..	..	..	..	..	..	..	..	12·5	..
„ house	..	..	..	..	..	77	..	..	..	..	..	..	..	..	23	..
Brass, best	..	..	..	..	..	71·4	..	..	..	..	..	..	..	..	..	28·6
„ common	..	..	..	..	..	66·6	..	..	..	..	..	..	..	..	..	33·3
„ „	..	..	..	..	..	84·3	..	..	..	..	..	..	..	..	10·5	5·2
„ „	..	..	..	..	..	75	..	..	..	..	..	..	..	..	..	25

Table 142—*continued.*

	Aluminium.	Antimony.	Arsenic.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Platinum.	Silicium.	Silver.	Tin.	Zinc.
Brass for bearings	..	..	..	..	..	90	..	..	..	..	..	..	..	..	9	1
" " bushes	..	..	..	..	..	18	..	..	..	..	..	..	..	..	..	1
" " instruments ..	..	..	..	..	..	92·2	..	..	..	..	..	..	..	..	7·8	..
" " soldering	..	..	..	..	..	2·6	..	..	..	..	..	..	..	..	..	1
" " taps	..	..	..	..	..	2·5	..	..	1	..	..	..	..	..	..	..
" " turning	..	..	..	..	..	3	..	..	·85	..	..	..	..	..	..	1
" hard	..	..	..	..	..	79·3	..	..	..	..	..	..	..	..	14·3	6·4
" pinchbeck	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	1
" pin wire	..	..	..	..	..	63	..	..	..	..	..	..	..	..	..	37
" red tombac	..	..	..	..	..	88·8	..	..	..	..	..	..	..	..	..	11·2
" rolled	..	..	..	..	..	74·3	..	..	..	..	..	..	..	..	3·4	22·3
" tenacious	..	..	..	..	..	88·9	..	..	..	..	..	..	..	..	8·3	2·8
" tutenag	..	..	..	..	..	50	..	..	..	..	19	..	..	..	..	31
" "	..	..	..	..	..	45·7	..	..	..	..	17·4	..	..	..	..	36·9
" valves	..	..	..	..	..	90	..	..	..	..	..	..	..	..	10	..
" wheels	..	..	..	..	..	90	..	..	..	..	..	..	..	..	10	..
" white	..	..	..	..	..	10	..	..	..	..	..	..	..	..	10	80
" "	..	7	..	..	..	3	..	..	..	..	..	..	..	..	..	90
" "	47	..	..	..	..	7	..	..	46	..	..	..	..	..	..	..
" wire	..	..	..	..	..	67	..	..	..	..	..	..	..	..	..	34
" yellow	..	..	..	..	..	66	..	..	..	..	..	..	..	..	..	34
" "	..	..	..	..	..	60	..	..	..	..	..	..	..	..	..	40
Britannia metal	..	6·2	..	..	..	1·8	..	..	..	..	..	..	..	..	92	..
" "	..	50	..	25	..	..	..	..	..	..	..	..	..	..	25	..
Bronze, coin	..	..	..	..	..	95	..	..	..	..	..	..	..	..	4	1
" cymbals	..	..	..	..	..	80	..	..	..	..	..	..	..	..	20	..
" for bearings	..	..	..	..	..	82	..	..	..	..	..	..	..	..	16	2

Table 142—*continued.*

	Aluminium.	Antimony.	Cobalt of iron.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Phosphorus.	Silicium.	Silver.	Tin.	Zinc.
Bronze for bearings	..	..	..	..	..	6	..	..	..	..	..	..	..	..	17	77
„ „ „	..	..	..	..	..	80	..	..	..	..	..	..	..	..	18	2
„ „ „	..	..	..	..	..	82	..	..	..	..	..	..	..	..	5	1
„ „ „	..	..	..	..	..	8	..	..	..	..	..	..	..	..	1	..
„ „ valves	..	..	..	..	..	88	..	..	..	..	..	..	..	..	2	10
„ „ wheels	..	..	..	..	..	10	..	..	..	..	..	..	..	..	1	..
„ medal	..	..	..	..	..	93	..	..	..	..	..	..	..	..	7	..
„ red	..	..	..	..	..	87	..	..	..	..	..	..	..	..	..	13
„ „	..	..	..	..	..	86	..	..	..	..	..	..	..	..	2·9	11·1
„ statuary	..	..	..	..	..	91·4	..	..	1·7	..	..	..	..	..	1·4	5·5
„ yellow	..	..	..	..	..	67·2	..	..	..	..	..	..	..	..	1·6	31·2
Chinese silver	..	..	11·1	..	..	58·1	..	..	..	..	11·6	..	..	2	..	17·2
„ white copper	..	..	..	..	..	40·4	..	..	..	..	31·6	..	..	..	2·6	25·4
Delta metal, castings	..	..	..	..	..	55·94	..	·87	·72	·61	trace	·013	..	..	..	41·61
„ „ forgings	..	..	..	..	..	55·80	..	1·28	1·82	·96	trace	·011	..	..	..	40·07
„ „ hot hammered	..	..	..	..	..	54·22	..	·99	1·10	1·09	·16	·02	..	..	..	42·25
„ „ turnings	..	..	..	..	..	55·82	..	·86	·76	1·38	·06	trace	..	..	..	41·41
Dutch metal	..	..	..	..	..	84·6	..	..	..	..	..	..	..	..	..	15·4
Electrum	..	..	..	..	..	51·6	..	..	..	..	25·8	..	..	..	..	22·6
Expands in cooling	..	16·7	..	8·3	..	..	..	..	75	..	..	..	..	..	..	..
Fusible metal	..	..	..	20	..	..	..	..	50	..	..	..	..	..	30	..
„ „	..	..	..	50	..	..	..	..	25	..	..	..	..	..	25	..
„ „	..	..	..	50	12·5	..	..	..	25	..	..	..	..	..	12·5	..
„ „	..	..	..	33·4	..	..	..	..	33·3	..	..	..	..	..	..	33·3
„ „	..	..	..	50	..	..	..	..	31	..	..	..	..	..	19	..
Gedge „	..	..	..	..	..	60	..	1·8	..	..	..	..	..	..	..	38·2
German silver	..	..	..	..	..	40–60	..	..	..	..	20–30	..	..	..	..	20–30

Table 142—*continued.*

	Aluminium.	Antimony.	Arsenic.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Phosphorus.	Silicium.	Silver.	Tin.	Zinc.
German silver	..	..	..	..	..	33·3	..	..	..	..	33·3	..	..	..	..	33·4
" "	..	..	..	..	..	40·4	..	2·6	..	..	31·6	..	..	..	..	25·4
" " fine	..	..	..	..	..	49·5	..	2·5	..	..	24	..	..	..	..	24
" " plate	..	..	..	..	..	55	..	2	..	..	24	..	..	..	3	16
Gold coin	..	..	..	..	..	8·33	91·66	..	..	..	..	..	..	..	..	..
Gongs	..	..	..	..	..	81·6	..	..	..	..	..	..	..	..	18·4	..
Gun-metal	..	..	..	..	..	90	..	..	..	..	..	..	..	..	10	..
" small	..	..	..	..	..	93	..	..	..	..	..	..	..	..	7	..
" soft	..	..	..	..	..	95	..	..	..	..	..	..	..	..	5	..
" "	..	..	..	..	..	16	..	..	..	..	..	..	..	..	1	..
" turning	..	..	..	..	..	5	..	..	..	..	..	..	..	..	1	..
Japanese bronze	..	..	..	..	..	76–87	..	..	..	..	..	..	..	..	13–23	..
" kuromi	..	1·96	..	..	..	98·04	..	..	..	..	..	..	..	..	..	..
" shaku-do	..	..	traces	..	..	94·50	3·73	traces	·11	..	..	..	..	1·55	..	..
" shibu-ishi	..	..	..	..	..	67·31	traces	..	·52	..	..	..	..	32·07	..	..
Machine bearings..	..	..	..	..	..	87·5	..	..	..	..	..	..	..	..	12·5	..
" "	..	..	..	..	..	77·4	..	..	..	..	..	..	..	..	15·6	7
Mira metal	..	6·78	..	..	..	74·75	..	·34	16·35	..	·24	..	..	..	·91	·61
Muntz metal	..	..	..	..	..	60–64	..	..	..	..	..	..	..	..	..	36–40
" "	..	..	..	..	..	3	..	..	·009	..	..	..	..	..	..	2
" " nails	..	..	..	..	..	87	..	..	..	..	..	..	..	..	9	4
Pewter, best	..	14	..	..	..	..	..	..	..	..	..	..	..	..	86	..
" ley	..	..	..	..	..	..	..	..	20	..	..	..	..	..	80	..
" plate..	..	7	..	2	..	2	..	..	..	..	..	..	..	..	89	..
" triple	..	15	..	..	..	..	..	..	6	..	..	..	..	..	79	..
Pinchbeck	..	..	..	..	..	80	..	..	..	..	..	..	..	..	..	20
Sheathing	..	..	..	..	..	56	..	..	..	..	..	..	..	..	..	44

Table 142—*continued.*

	Aluminium.	Antimony.	Arsenic.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Phosphorus.	Silicium.	Silver.	Tin.	Zinc.
Silicium brass	..	..	..	..	..	71·30	..	·38	·74	..	..	..	·14	..	·57	26·65
" wire	..	..	..	..	..	99·94	..	trace	..	..	..	..	·02	..	·03	..
" "	..	..	..	..	..	97·12	..	trace	..	..	..	..	·05	..	1·14	1·62
Silver coin	..	..	..	..	..	7·5	..	..	..	..	..	..	..	92·5	..	..
Solder, aluminium	6	..	..	..	..	4	..	..	..	..	..	..	..	..	..	90
" brazing	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1
" coarse..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	1	..
" common	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..
" "	..	..	..	..	..	..	..	..	1	..	..	..	..	..	2	..
" copper	..	..	..	..	..	53	..	..	..	..	..	..	..	..	47	..
" fine	..	..	..	..	..	..	..	..	1	..	..	..	..	..	2	..
" " brass	..	..	..	..	..	47	..	..	..	..	..	..	..	6	..	47
" glaziers'	..	..	..	..	..	..	..	..	1	..	..	..	..	..	3	..
" gold	..	..	..	..	..	22·2	66·6	..	..	..	..	..	..	11·1	..	..
" "	..	..	..	..	..	4	89	..	..	..	..	..	..	7	..	..
" hard	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	2
" iron	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	1
" lead	..	..	..	..	..	..	..	..	2	..	..	..	..	..	1	..
" pewterers'..	..	..	..	11·8	..	..	..	..	29·4	..	..	..	..	..	58·8	..
" "	..	..	..	22	..	..	..	..	45	..	..	..	..	..	33	..
" "	..	..	..	25	..	..	..	..	25	..	..	..	..	..	50	..
" "	..	..	..	40	..	..	..	..	20	..	..	..	..	..	40	..
" plumbers' coarse ..	..	..	..	..	..	..	..	..	3	..	..	..	..	..	1	..
" " fine ..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	2	..
" " fusible ..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..
" " " ..	..	..	..	2	..	..	..	..	1	..	..	..	..	..	1	..
" " potmetal	..	..	..	..	..	..	..	..	2	..	..	..	..	..	1	..

Table 142—*continued.*

	Aluminium.	Antimony.	Arsenic.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Phosphorus.	Silicium.	Silver.	Tin.	Zinc.
Solder, silver	..	..	..	..	..	20	..	..	..	..	..	..	..	80	..	..
„ „	..	..	..	..	..	32·3	..	..	..	..	..	..	..	38·5	..	29·2
„ „ soft..	..	..	..	..	21	12	..	..	..	..	..	..	..	67	..	..
„ spelter, hard	..	..	..	..	..	65	..	..	..	..	..	..	..	..	..	35
„ „ „	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	2
„ „ soft	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1
„ tin	..	10	..	16	..	..	..	..	16	..	..	..	..	..	58	..
Speculum metal	..	..	..	..	..	66·6	..	..	..	..	..	..	..	..	33·3	..
„ „	..	..	12	..	..	66	..	..	..	..	..	..	..	..	22	..
„ „	..	..	..	..	..	50	..	..	..	..	..	..	..	..	29	21
Spelter, hard	..	..	..	..	..	65	..	..	..	..	..	..	..	..	..	35
„ soft	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1
Sterro metal	..	..	..	..	..	55–60	..	..	2–4	..	..	..	..	..	1–2	34–44
Telescopic mirrors	..	..	..	..	..	66·6	..	..	..	..	..	..	..	..	33·4	..
Temper	..	..	..	..	..	33·4	..	..	..	..	..	..	..	..	66·6	..
Tombac	..	..	..	..	..	88·8	..	..	..	..	..	..	..	..	..	11·2
Tutenag	..	..	..	..	..	50	..	..	..	..	19	..	..	..	..	31
„	..	..	..	..	..	45·7	..	..	..	..	17·4	..	..	..	..	36·9
Type metal	..	25	..	..	..	..	..	..	75	..	..	..	..	..	..	..
„ „	..	25	..	..	..	..	..	..	50	..	..	..	..	..	25	..
„ „	..	12·5	..	..	..	..	..	..	87·5	..	..	..	..	..	..	..
White metal	..	56·8	..	..	..	7·4	..	..	..	..	..	..	..	..	28·4	7·4
„ „	..	..	..	..	..	69·8	..	..	..	..	..	..	..	..	4·4	25·8
„ „	..	7	..	..	..	3	..	..	..	..	..	..	..	..	90	..
„ „	..	42	..	..	..	6	..	..	42	..	..	..	..	..	..	..

Action of Acid and Alkaline Solutions on Metals. (Lunge.)

At ordinary temperatures, and with exclusion of air, the action of sulphuric acid, pure or commercial, at strengths of 66° to 50° B., is very insignificant on cast iron, and noteworthy differences as regards the various qualities of iron could not be distinguished. At the boiling point of water the action is much greater, that of acid at 66° B. being the slightest, that of acid at 60° B. 1½ times greater, and that of acid at 50° B. three times greater.

The differences at the boiling points of the acids are much more decided. Acid of 66° B. has little more action at its boiling point (295°) than at 100°; acid of 60° B. acts at its boiling point (200°) on the average 14 times stronger than at 100°, and 20 times stronger than the 66° acid at 295°. The 50° B. acid, which at 100° acts twice as strongly as that of 60° B., acts at its boiling point (147°) less strongly than that of 60° B. at 200°.

As to the action of monohydrated sulphuric acid upon cast iron, wrought iron, copper, and lead, at common temperatures and at 100° there is very little action, either upon cast or wrought iron, if air is excluded. Copper and lead are strongly attacked at common temperatures—lead more than copper. At 100°, lead is scarcely more affected than at 20°, while copper enters into violent reaction, with escape of sulphurous acid.

With saturated solutions of sodium chloride and ammonium chloride upon the same metals. Sodium chloride attacks slightly in all cases, but quite perceptibly, especially on cast iron, and at higher temperatures on lead. The action of ammonium chloride is much stronger. Contrary to the common opinion, lead is much more attacked in the cold by a strong solution of sal ammoniac than iron. At a boiling heat it resists far better than iron, but far worse than copper.

Caustic soda has little action upon iron at 15° and 100°, but more upon wrought iron than cast iron. Upon copper the action is more considerable, and upon lead still more so if the lye is dilute. Sodium sulphide, even in dilute solution, has a much stronger action upon iron and copper. Upon lead the action is slight, even at 100°. Sodium sulphate has little effect upon copper and lead, but its action upon iron is considerable.

Table 143.—*Properties of Metals.*

Metal.	Symbol.	Sp. gr.	Atomic weight.	Fusing point. ° F.	Expansion of 1 from 32° to 212° F.	Tensile strength per sq. in. Tons.	Weight per cub. ft. lb.	Tenacity.	Malleability.	Ductility.	Heat conductivity.	Electric conductivity.	Affinity for sulphur.
Aluminium..	Al	2·67	27·0	1292	·0022	12	166·8	..	..	7	4	..	..
Antimony	Sb	6·72	122·0	1159	·0011	½	419·5	..	..	..	10	46	7
Arsenic	As	5·9	75·0	..	..	..	..	..	..	..	..	..	14
Barium..	Ba	4·0	137·0	2190	..	..	..	..	..	..	..	..	..
Beryllium	Be	2·1	9·0	..	..	..	..	..	..	..	..	..	..
Bismuth	Bi	9·8	208·0	507	·0014	1½	613	..	..	..	11	12	5
Boron	B	2·7	11·0	..	..	..	..	..	..	..	..	..	..
Bromine	Br	3·2	80·0	–13	..	..	..	..	..	..	..	..	..
Cadmium	Cd	8·69	112·0	442	·0031	..	542·5	..	..	..	..	..	6
Cæsium	Cs	1·9	133·0	77	..	..	..	..	..	..	..	..	..
Calcium	Ca	1·6	40·0	..	..	..	..	..	..	..	..	..	..
Carbon	C	..	12·0	..	..	..	..	..	..	..	..	..	..
Cerium..	Ce	6·7	92·0	..	..	..	..	..	..	..	..	..	..
Chlorine	Cl	..	35·5	..	..	..	..	..	..	..	..	..	..
Chromium	Cr	7·3	52·5	..	..	..	..	..	..	..	..	..	..
Cobalt	Co	8·5	59·0	2730	..	16–29	558·7	..	..	..	..	..	12
Copper	Cu	8·9	63·5	1996	·0017	13–15	558·1	18	3	5	3	999	4
Didymium	Di	6·5	145·0	..	..	..	..	..	..	..	..	..	..
Erbium..	Er	..	[96] 166·3	..	..	..	..	..	..	..	..	..	..
Fluorine	F	..	19·0	..	..	..	..	..	..	..	..	..	..

Table 143—*continued.*

Metal.	Symbol.	Sp. gr.	Atomic weight.	Fusing point. ° F.	Expansion of 1 from 32° to 212° F.	Tensile strength per sq. in. Tons.	Weight per cub. ft. lb.	Tenacity.	Malleability.	Ductility.	Heat conductivity.	Electric conductivity.	Affinity for sulphur.
Gallium	Ga	5·9	70·0	86	..	..	..	..	..	..	..	..	..
Germanium..	Ge	..	72·3	..	..	..	..	..	..	..	..	..	..
Glucinum	Gl	..	9·0	..	..	..	..	..	..	..	..	..	..
Gold	Au	19·2	196·7	2192 [2000]	..	..	..	12	1	1	2	779	..
Hydrogen	H	..	1·0	..	..	..	..	..	..	..	..	..	..
Indium..	In	7·4	113·7 [74]	347	..	..	..	..	..	..	..	..	..
Iodine	I	4·9	127·0	221	..	..	..	..	..	..	..	..	..
Iridium..	Ir	22·4	193·0 [198]	4530	..	..	..	..	..	..	..	..	..
Iron	Fe	7·8	56·0	..	..	..	..	27·5	8	4	6	168	13
„ cast	..	..	..	2700	·0011	..	450–	..	..	..	..	..	..
„ wrought	..	..	..	3280	to	7–32	488	..	..	..	..	..	..
„ steel	..	..	..	3300 [4000]	·0028	..	..	42	..	..	..	..	..
Lanthanum..	La	6·1	138·8 [92]	..	..	..	..	..	..	..	..	..	..
Lead	Pb	11·4	206·9	635 [617]	..	..	..	1	6	10	9	83	9
Lithium	Li	0·59	7·0	356	..	..	..	..	..	..	..	..	..
Magnesium..	Mg	1·7	24·0	1380	..	..	..	..	..	..	..	..	..
Manganese	Mn	8·0	55·0	3450	..	..	..	..	..	..	..	..	16

Table 143—*continued.*

Metal.	Symbol.	Sp. gr.	Atomic weight.	Fusing point. °F.	Expansion of 1 from 32° to 212° F.	Tensile strength per sq. in. Tons.	Weight per cub. ft. lb.	Tenacity.	Malleability.	Ductility.	Heat conductivity.	Electric conductivity.	Affinity for sulphur.
Mercury	Hg	13·6	200·0	—40	..	..	..	..	..	..	..	..	2
Molybdenum	Mo	8·6	96·0	..	..	..	..	..	..	..	..	..	..
			[92]										
Nickel	Ni	8·9	58·5	2910	..	..	..	..	..	..	..	131	11
Niobium	Nb	4·1	94·0	..	..	..	..	..	..	..	..	..	..
Nitrogen	N	..	14·0	..	..	..	..	..	..	..	..	..	..
Osmium	Os	22·4	199·0	4530	..	..	..	..	..	..	..	..	..
Oxygen	O	..	16·0	..	..	..	..	..	..	..	..	..	..
Palladium	Pd	11·4	106·0	2462	..	..	..	11·5	..	6	..	184	1
Phosphorus	P	..	31	..	..	..	..	..	..	..	..	..	..
Platinum	Pt	21·5	194·9	3632	..	..	..	15	5	3	8	180	..
			[197]	[3280]									
Potassium	K	0·86	39·1	144·5	..	..	..	..	..	..	..	..	..
Rhodium	Rh	12·1	104·3	3630	..	..	..	..	..	..	..	..	..
Rubidium	Rb	1·5	85·5	97·7	..	..	..	..	..	..	..	..	..
Ruthenium	Ru	11·4	104·5	3270	..	..	..	..	..	..	..	..	..
Scandium	Sc	..	44·0	..	..	..	..	..	..	..	..	..	..
Selenium	Se	4·8	79·0	212	..	..	..	..	..	..	..	..	..
Silicon	Si	2·0	28·0	..	..	..	..	..	..	..	..	..	..
Silver	Ag	10·5	107·9	1832	..	..	..	12·5	2	2	1	1000	3
Sodium	Na	0·97	23·0	204	..	..	..	..	..	..	..	..	..

Table 143—*continued.*

Metal.	Symbol.	Sp. gr.	Atomic weight.	Fusing point. °F.	Expansion of 1 from 32° to 212° F.	Tensile strength per sq. in. Tons.	Weight per cub. ft. lb.	Tenacity.	Malleability.	Ductility.	Heat conductivity.	Electric conductivity.	Affinity for sulphur.
Strontium	Sr	2·5	87·5	..	..	..	..	..	..	..	..	..	..
Sulphur	S	2·0	32·0	239	..	..	..	..	..	..	..	..	..
Tantalum	Ta	..	182·5	..	..	..	..	..	..	..	..	..	..
Tellurium	Te	6·2	128·0	896	..	..	..	..	..	..	..	..	..
Thallium	Tl	11·9	204·0	562	..	..	..	..	..	..	..	..	15
Thorium	Th	7·8	233·5	..	..	..	..	..	..	..	..	..	..
Tin	Sn	7·3	118·0	455	..	..	..	1·3	4	9	7	123	8
„ cast	..	..	..	[442]									
Titanium	Ti	5·3	50·0	..	..	..	..	..	..	..	..	..	..
Tungsten	W	19·1	184·0	..	..	..	..	..	..	..	..	..	..
Uranium	U	18·4	239·0	..	..	..	..	..	..	..	..	..	..
Vanadium	V	5·5	51·3	..	..	..	..	..	..	..	..	..	..
Ytterbium	Yb	..	[137] 173·1	..	..	..	..	..	..	..	..	..	..
Yttrium	Y	..	90·0	..	..	..	..	..	..	..	..	..	..
Zinc	Zn	6·9	65·0	758	..	..	..	2	7	8	5	290	10
„ cast	..	..	..	[770]									
Zirconium	Zr	4·1	89·5	..	..	..	..	..	..	..	..	..	..

Table 144.—*Tenacity of Metals at Various Temperatures.*
Tensile Strength and Elastic Limits in tons per sq. in. Elongation in %. D = Ductility.

Temperature.	Bar Iron.		Boiler Plate Iron.		Mild Steel.		Gun Metal. Copper 87·75 Tin 9·75 Zinc 2·5		Brassy Gun Metal. Copper 83 Tin 2 Zinc 15		Phosphor-Bronze. Cast.		Rolled Copper.		Rolled Bull's Metal.		
	Tensile.	Elong.	Tensile.	Elong.	Tensile.	Elong.	Tensile.	D.	Tensile.	D.	Tensile.	D.	Tensile.	D.	Tensile.	Elastic L.	Elong. in 6 in.
° Atmospheric Temperature	21·1	15·6	23·9	24	28·5	22	15·3	12·5	13·86	26	17·4	17·5	25·4	2·5	32·69	28·72	18·3
100	21·4	..	..	..	..	..	14·43	10	13·71	26	17·55	17	25·7	2·5	..	..	..
150	..	..	..	..	..	..	15·0	11	12·86	25·5	17·43	18	24·5	4	..	..	..
200	..	..	..	..	..	..	13·86	10	13·16	26·25	17·28	18	24·3	5	..	..	..
250	..	..	..	..	..	..	14·43	10	12·56	26	16·57	15	23·7	7	..	..	..
300	22·25	..	..	..	..	..	14·28	10	12·41	23	16·42	12	23·7	6	27·10	22·66	18
350	..	..	..	..	..	..	12·86	8·25	12·41	25	13·15	7	23·7	6	..	..	..
400	..	..	..	..	38·4 / 430°	18·75	7·0	0·75	12·41	25	12·11	5	23·2	6	25·35	21·07	19·8
450	..	..	27	8·6	..	..	7·57	Nil	4·34	1·2	10·86	4	22·9	6	..	..	..
500	..	12·5	27·4	12·5	33 / 550°	17·2	7·14	Nil	4·34	Nil	12	5	21·5	6	..	..	..
850/900	19·3	18·75	..	..	18·5 / 580°	25	..	..	..	..	..	..	..	..	..	..	..

Table 145.—*Weight of Various Rolled Metals in lb. per lineal ft.*

Size of Bar.	Iron.		Phosphor-Bronze.		Bull's Metal.	
	Square	Round.	Square.	Round.	Square	Round.
in.						
1/4	·209	·164	·24	·19	·225	·177
5/16	·326	·256	·38	·30	·353	·278
3/8	·470	·369	·55	·43	·510	·400
7/16	·640	·502	·74	·58	·690	·541
1/2	·835	·656	·97	·76	·902	·708
9/16	1·057	·831	1·23	·96	1·144	·895
5/8	1·305	1·025	1·52	1·19	1·412	1·107
11/16	1·579	1·241	1·83	1·44	1·70	1·34
3/4	1·879	1·476	2·18	1·72	2·03	1·60
13/16	2·205	1·732	2·56	2·01	2·38	1·86
7/8	2·556	2·011	2·97	2·33	2·76	2·17
15/16	2·936	2·306	3·41	2·68	3·17	2·49
1	3·34	2·62	3·88	3·05	3·61	2·83
1 1/16	3·76	2·96	4·38	3·44	4·07	3·20
1 1/8	4·22	3·32	4·91	3·86	4·56	3·54
1 3/16	4·71	3·68	5·47	4·30	5·09	4·00
1 1/4	5·25	4·09	6·06	4·77	5·65	4·43
1 5/16	5·77	4·50	6·68	5·25	6·23	4·87
1 3/8	6·35	4·96	7·34	5·77	6·85	5·37
1 7/16	6·90	5·41	8·02	6·30	7·46	5·85
1 1/2	7·51	5·90	8·73	6·86	8·12	6·38
1 9/16	8·12	6·38	9·48	7·45	8·80	6·92
1 5/8	8·82	6·92	10·25	8·05	9·54	7·49
1 11/16	9·51	7·44	11·05	8·69	10·28	8·07
1 3/4	10·29	8·03	11·89	9·34	11·09	8·69
1 13/16	10·97	8·59	12·75	10·02	11·86	9·31
1 7/8	11·74	9·22	13·65	10·72	12·69	9·97
1 15/16	12·52	9·82	14·57	11·45	13·55	10·64
2	13·36	10·49	15·53	12·20	14·45	11·35
2 1/16	14·20	11·14	16·51	12·97	15·36	12·06
2 1/8	15·08	11·84	17·53	13·77	16·31	12·81
2 3/16	15·97	12·53	18·58	14·60	17·28	13·57
2 1/4	16·91	13·27	19·65	15·44	18·28	14·36
2 5/16	17·85	14·01	20·76	16·31	19·31	15·16
2 3/8	18·84	14·79	21·90	17·20	20·37	16·00
2 7/16	19·83	15·57	23·06	18·12	21·45	16·85
2 1/2	20·87	16·39	24·26	19·06	22·57	17·73
2 5/8	23·11	18·07	26·75	21·02	24·93	19·55
2 3/4	25·26	19·84	29·36	23·07	27·31	21·46
2 7/8	27·61	21·68	32·06	25·21	29·84	23·45
3	30·07	23·60	34·94	27·45	32·51	25·53
3 1/4	35·28	27·70	41·01	32·20	38·15	29·95
3 1/2	40·91	32·13	47·56	37·34	44·24	34·74
3 3/4	46·97	36·89	54·57	42·87	50·77	39·88
4	53·44	41·97	62·1	48·78	57·77	45·38
4 1/4	60·32	47·38	70·1	55·05	65·21	51·22
4 1/2	67·63	53·12	78·26	61·48	73·95	57·30
4 3/4	75·35	59·18	87·6	68·8	81·48	64·00
5	83·51	65·58	97·00	76·18	90·26	70·88
5 1/4	92·46	72·30	107·00	84·04	99·73	78·17
5 1/2	101·03	79·35	117·5	92·3	109·27	85·83
5 3/4	110·43	86·73	128·35	101·7	119·39	94·22
6	120·25	94·43	139·7	109·8	130	102·12
12	481	377·9	559	439	520	408·5

Table 146.—*Co-efficients of Strength of Various Materials.*

Material.	Safe Limits of Stress. Tension.	Safe Limits of Stress. Com-pression.	Safe Limits of Stress. Shearing.	Stress at Elastic Limit. Tension.	Stress at Elastic Limit. Com-pression.	Stress at Elastic Limit. Shearing.	Breaking Stress. Tension.	Breaking Stress. Com-pression.	Breaking Stress. Shearing.	Elastic Modulus. Tension. Com-pression.	Elastic Modulus. Shearing.	Extension at Breaking Point % (in 10″).	Extension at Elastic Limit in Terms of Unity. Tension.	Extension at Elastic Limit in Terms of Unity. Com-pression.
	Tons per sq. in.													
Wrought iron bars..	4·5	4·5	3·8	12·0	11·5	9·0	23·0	20·0	20·0	13,000	4,800	12	·0009	·0009
„ boiler plates ..	4·5	4·5	3·8	15·0	14·0	11·0	23·0	19·0	18·0	14,000	4,900	16	·00108	·001
„ ship plates ..	4·5	4·5	3·8	15·5	14·0	11·0	23·0	19·0	18·0	14,000	4,900	7	·0011	·001
„ wire, hard ..	7·6	..	..	14·0	..	..	46·0	..	..	12,700	4,760	0·5	·0011	..
„ „ soft ..	5·5	..	..	..	..	..	30·0	..	..			20		
Cast iron	1·6	4·5	1·25	4·75	9·5	3·5	8·5	45·0	5–7	$\frac{6300}{5900}$	2,380	..	·00075	·0016
Steel, mild	5·5	5·5	4·5	18·0	17·0	..	28·0	50·0	24·0	$\frac{14000}{16500}$	5,400	22	·0013	·00106
„ (8 % C.)..	..	..	..	25·5	28·0	..	46·0	..	30·6	$\frac{13900}{14500}$	..	9	·0018	·002
„ rails	..	..	..	23·0	..	..	38·0	..	..	..	..	16	..	..
„ castings..	4·5	4·5	..	14·0	13·0	..	35 0	..	..	11,000	..	5	·0012	·0012
„ wire	..	..	..	..	..	..	62·0	..	..	..	..	4	..	..
Copper, rolled hard	1·75	1·75	1·25	..	..	..	18·0	45 (?)	18·0	6,800	2,540	..	..	..
„ annealed	1·2	1·2	·9	2·8	1·75	1·25	13·5	26·0	13·5	5,130	2,540	35	·00056	..
„ wire, hard	4·2	4·2	3·2	8·9	8·9	6·67	26·0	..	..	6,680	..	..	·0012	·0012
„ „ soft	1·6	1·25	1·0	3·5	..	..	20·0	..	..	to 7,650	..	45	·0005	..
Brass, cast 75 Cu., 25 Zn. ..	1·6	1·6	1·25	5·0	12·0	..	13·5	19·0	..	5,800	..	30	·00086	..
„ wire	4·2	..	3·2	8·5	..	..	25·0	..	..	6,300	..	25	·0013	..
Gun metal, 9 Cu., 1 Sn. ..	2·0	..	..	8·0	..	..	12·0	16·0	..	6,250	..	3·5	·0012	..
Phosphor-bronze, II., cast ..	3·0	..	..	7·8	8·7	..	15·8	50·0	..	7,100	..	17·5	·0011	·0012
„ VI., chill cast	4·0	..	..	9·3	8·9	..	25·4	50 0	..	7,100	..	21·3	·0011	·0012
„ drawn bars ..	6·5	..	..	84·5	..	..	36	..	..	..	..	10	..	..
Bull's metal, cast	4·0	5·0	..	12·0	15·5	..	21·0	78·75	..	7,000	..	8	·0017	·0022
„ forged	5·0	6·0	..	10·0	..	..	28·0	..	..	6,500	..	30	·0015	..
„ rolled	5·5	..	..	20	..	..	33·0	..	..	6,500	..	20	·0031	..
„ „ and cold finished	6·5	7·5	..	28·5	23·5	..	35·5	100	..	7,500	..	12	·0038	·0031

The factor of safety in first columns is reckoned as about 5 to 6; in cases where the stresses are intermittent, increase factor of safety 7 or 8; where the stresses are reversed (as tension and compression alternately), increase to about 10 for rolled iron, steel, Bull's metal

Table 147.—*Working Strains of Bolts in Various Metals.*

Diameters.		Nett Area: sq. in.	Working Strain in lbs.					
in.	Under Thread.		A 4000 lb. per sq. in.	5000 lb. per sq. in.	B 6000 lb. per sq. in.	7000 lb. per sq. in.	C 8000 lb. per sq. in.	D 10,000 lb. per sq. in.
3/8	·295	·0683	273	341	410	478	546	683
1/2	·393	·1313	485	606	728	849	970	1,213
5/8	·509	·2034	814	1,017	1,220	1,423	1,627	2,034
3/4	·622	·3038	1,215	1,519	1,823	2,127	2,430	3,038
7/8	·733	·4219	1,688	2.110	2,531	2,953	3,375	4,219
1	·840	·5541	2,216	2,770	3,325	3,879	4,433	5,541
1 1/8	·942	·6969	2,788	3,485	4,181	4,878	5,575	6,969
1 1/4	1·067	·8941	3,576	4,470	5,365	6,259	7,153	8,941
1 3/8	1·162	1·0604	4,242	5,301	6,362	7,422	8,483	10,604
1 1/2	1·287	1·3009	5,204	6,505	7,805	9,106	10,407	13,009
1 5/8	1·369	1·4720	5,888	7,360	8,832	10,304	11,776	14,720
1 3/4	1·494	1·7530	7,012	8,765	10,518	12,271	14,024	17,530
1 7/8	1·590	1·9855	7,942	9,928	11,931	13,917	15,884	19,855
2	1·715	2·3100	9,240	11,550	13,860	16,170	18,480	23,100
2 1/4	1·930	2·9255	11,702	14,627	17,553	20,478	23,404	29,255
2 1/2	2·180	3·7325	14,930	18,662	22,395	26,127	29,860	37,325
2 3/4	2·384	4·4637	17,855	22,319	26,782	31,246	35,710	44,637
3	2·634	5·4490	21,796	27,245	32,694	38,143	43,592	54,490
3 1/2	3·105	7·572	30,288	37,860	45,432	53,004	60,576	75,720
4	3·573	10·040	40,160	50,200	60,240	70,280	80,320	100,400
4 1/2	4·054	12·910	51,640	64,550	77,460	90,370	103,280	129,100
5	4·534	16·140	64,560	80,700	96,840	112,980	129,120	161,400
6	5·487	23·600	94,400	118,000	141,600	165,200	188,800	236,000

A—Suitable for wrought iron, rolled Muntz metal and cast phosphor-bronze. B—Suitable for mild steel and forged Bull's metal.
C—Suitable for superior steel, rolled Bull's metal and rolled phosphor-bronze.
D—Suitable for cold rolled steel, cold rolled Bull's metal, and cold rolled phosphor-bronze.

VALUING METALS AND ORES.

Aluminium.—The mineral worked as a source of the metal should be as free as possible from iron, and as rich as possible in alumina. Cryolite, consisting when pure of 13 per cent. aluminium, combined with 54 of fluorine and 33 of sodium, is always more or less contaminated with iron and silicon compounds which give much trouble; when the total impurities reach 20 per cent. the mineral is commercially worthless. Bauxite, affording about half its weight of alumina, is liable to the same faults. Average samples will show 55-58 per cent. alumina, 3-20 per cent. silica, 2-25 per cent. iron oxide, 11-30 per cent. water; the maximum figures of silica and iron lower the value greatly. The same may be said of kaolins as a source of the metal.

Aluminium should contain no silica or iron, but it may safely be said that all found in commerce does contain both. The silica occurs in two forms—as a silicide of aluminium and in the graphitoidal form. Commercial brands show the following composition:—

	%
Aluminium	95—99·30
Iron	·03— 3·25
Silicon combined	·23— 1·75
„ graphitoidal	·13— 1·35
Copper	nil— ·10
Sodium	nil— ·30
Lead	nil— ·04

Antimony.—Ores of antimony, the oxide and sulphide, are sold on a basis of 45 per cent. of metal, the market value per ton being of course liable to fluctuate in sympathy with the current price of the metal. These fluctuations are apt to be sudden and considerable. Each unit above 45 per cent. is worth so much per ton extra, say 8*s.* to 9*s.* per unit when the standard is worth 25*l.* a ton; while ore carrying less than 45 per cent. is subject to a discount at the same ratio, so that with a poor ore it is obvious that a limit is soon reached when the price becomes a negative quantity. Other conditions, such as size and impurities, further affect the market value. Thus, in dressing the ore it is essential that it should not be reduced in size much below that of hazel nuts. Of the impurities, especially in the sulphide, the worst is lead; 1 per cent. of lead will often make an otherwise good ore unsaleable. Copper, arsenic, and zinc are also objectionable, and reduce the value. Silver adds to the value if in appreciable quantity. The usual basis of sale is the assay value of metal computed on the dry ore. Nevertheless, smelters often prefer to base their offer for a parcel on the result of an actual smelting of a sample of two or

Antimony—continued.
three cwt., which enables them to judge of the behaviour of the ore in the furnace, whether it yields its metal readily, and does not suffer much loss in the slag.

Copper.—Though a large proportion of the copper and copper ores now brought into the market are sold by assay, the antiquated and cumbersome system of "ticketing" still survives sufficiently to demand description here.

"Ticketings," as held in Cornwall and Wales, are periodical auctions, at which buyers make bids (written on tickets) for such parcels of ore as they may have previously sampled and assayed. The value of the parcel is worked out as follows.

The "standard" is the actual value per ton of twenty-one cwt. of the fine copper contained in the ore, which is made up of the price paid for it added to the "returning charges," or cost incurred in extracting it from the ore. Then the market value of the parcel of ore is the amount arrived at by reckoning the "settled produce" or fine copper yielded by it at standard, and deducting the returning charges. These latter vary. In Cornwall they are fixed at 55s. per ton of ore, whether the ore is rich or poor. In Swansea they vary with the character of the ore, and consist of two items, one being a fixed rate of 12s. 2d. per ton of ore, and the other a charge of 3s. 9d. per unit of metal in the ore. The following examples calculated out will make the matter clearer :—

A. *Finding Standard.*—(Cornwall).

328 tons ore gave 21 tons fine copper, or about 6·4 per cent.

328 tons × 55*s*. returning charges	=	902	0	0	
Ticket offer for parcel	=	820	0	0	
21 tons fine copper into		1722	0	0	
Gives a standard of		£82	0	0	per ton.

B. *Finding "Value" of Parcel.*—(Cornwall).

76 tons ore at 4·55 per cent.	=	3·45 tons fine copper.			
Multiplied by		82*l*. per ton.			
		282	18	0	
Less returning charges at 55*s*. on 76 tons	=	209	0	0	
Value of parcel	=	£73	18	0	

C. *Finding "Returning Charges"*—(Swansea).

Ore at 5·75 per cent.

Fixed charge	=	0	12	2	per ton.
Sliding charge at 3*s*. 9*d*. per unit on 5·75 %	=	1	1	6	„
Total returning charges	=	£1	13	8	„

Copper—continued.

The presence of ·25 per cent. arsenic, or of ·01–·1 per cent. antimony, bismuth, or sulphur, or of 1–2 per cent. lead, is injurious. For electrical purposes, lead renders it unsaleable; but for many purposes a small amount of arsenic does not affect the value.

Iron.—Phosphorus is the most harmful impurity, and next ranks sulphur. An appreciable percentage of either will condemn a sample.

Lead.—Antimony, silver, and zinc are all detrimental. For pigment making, the presence of zinc does not so much matter, as the salt is white. For sheet lead for chemical manufacturers' purposes, the impurities named must be absent. Zinc not only reduces the value of the lead produced, but it also causes losses of metal by volatilisation and formation of fume. Antimony and arsenical pyrites are even more troublesome in this respect. Barytes interferes with the smelting operations and increases the consumption of fuel. The ore is valued for its lead contents per ton of 21 cwt. dry. Many lead ores contain silver. This does not add to the value of the sample unless it exceeds 5 oz. per ton. Against the assay value of the ore there is deducted a "returning charge," which varies according to the cost of fuel, rates of carriage, &c., and generally ranges between 2*l.* and 3*l.* a ton.

Manganese.—For Spanish and similar ores, the normal strength is 70 per cent. $Mn\ O_2$ in the ore dried at 212° F.; which means that 100 parts by weight of the ore liberate as much chlorine as 70 parts of pure $Mn\ O_2$ would do. The price of such ore fluctuates generally around 4*l.* per ton, with an addition or deduction of 2*s.* 6*d.* per unit for higher or lower quality, the minimum being usually 65 per cent. In the case of German ores, the normal strength is 60 per cent., the minimum 57 per cent., and the price per unit 2*s.* up or down. Of impurities, the most injurious are carbonates (of lime, &c.), as they not only consume hydrochloric acid, but also evolve carbonic acid, which has a most deleterious effect in bleaching-powder manufacture. The physical character of the ore is of some consequence, the soft varieties being most easily soluble in the acid, and therefore preferred. Some high-grade ores are so hard as to consume an excess of acid and steam, which greatly lowers their market value.

Nickel.—The presence of copper is highly injurious, as it cannot be separated except by wet process. Nevertheless, scarcely any ores are entirely free from copper.

Tin.—The confusing and old-fashioned method of computing the value of tin ore, by which the ignorant seller was robbed of at least one-third of the worth of his parcel, is now replaced by an accurate assay; the percentage of pure tin being worked out as tin oxide (black tin).

The presence of titanium does not affect the value to any

Tin—continued.
extent; but tungsten lowers the value; though, when a market can be found for the product, the ore may be freed from tungsten by treating with soda sulphate, and washing out the soda tungstate.

Zinc.—The chief deleterious ingredient of zinc ores is lead. The only ores absolutely free from lead are those from Lehigh. All others contain some small proportion, say ·01 per cent. Antimony, arsenic, cadmium, copper, iron, and lead are injurious both in the roasting of blende and in the subsequent distilling of the oxide. The smelter who buys blende or calamine bases his estimate of the value of a parcel of ore to him in somewhat the following way. He takes the market price of spelter, which may be assumed at 20*l.* a ton; from this he deducts 6*l.* per ton as the cost of smelting. Then from the zinc contents of the ore by assay, say 45 per cent., he deducts 15 per cent. if blende or 10 per cent. if calamine, as being the proportion of metal which will be lost in the slags and vapours, so that he has 30 or 35 per cent. of metal which he can reckon on extracting. Thus the market value of the zinc product of the ore is arrived at by a rule of three sum, e. g.,

$$\text{As } \frac{\text{Spelter}}{100\ \%} \text{ is worth } 14l. \text{ a ton, then } \frac{\text{Blende}}{30\ \%} \text{ is worth } 4l.\ 4s.$$

But as the smelter must make a profit, he offers such a figure below 4*l.* 4*s.* as will leave him the margin he desires. When the ore is very impure, more than 15 per cent. will be lost in the slags, &c.

ROASTING PYRITES.

The practice of roasting pyrites is almost as old as the gold-mining industry itself, and its importance is increasing rather than diminishing. It is true that some of the recently introduced chemical processes for recovering gold from sulphides have achieved a measure of success, but at present they are too costly to warrant their application to the thousands of tons of low-grade sulphurets being annually produced, and therefore it may be truly said that the problem of cheaply extracting small percentages of gold from refractory ores remains unsolved by them. About the sweet-roasting of auriferous sulphides and arseno-sulphides as a preliminary to amalgamation, there is the charm of simplicity, and hence it comes that the leading authorities of the day are looking to the invention of an improved furnace as the only efficient solution of the difficulty which is responsible for many mines being shut down or abandoned, and which is curtailing the income of almost every one. There is to-day certainly no subject connected with gold-mining which demands more careful consideration.

An experience of over 20 years with numerous forms of pyrites furnace leads the author to believe that in many instances the simplicity of the process has been the stumbling-block; that is to say, that operations have been undertaken with too little attention to the needs of the case. No doubt the liberation of sulphur and arsenic from an ore by means of heat is a very easy matter. A low temperature only is necessary, and the consumption of fuel is minimised by the fact that the sulphur and arsenic can be made to support their own combustion. For instance, in the sulphuric acid industry, where the primary object in roasting the pyrites is to recover the liberated sulphur as sulphurous oxide (except where the cinders are treated for copper), the ore is burned in thick beds in furnaces without any fuel whatever, the oxygen of the air admitted sufficing to support the combustion of the sulphur. In theory, while the combustion of coal produces a temperature of 2787° C., the combustion of iron pyrites should produce at least 1000° C., which is a higher temperature than is necessary for the operation, and allows a liberal margin for waste and imperfect combustion.

In the sulphuric acid makers' pyrites-kiln we have the simplest phase of the operation of sweet-roasting. The ores used, too, differ but slightly in their essential composition; yet even here, variations in the physical characters of ores will demand radically different types of furnace. Then it may be easily imagined that where the foremost object of the roasting is rather the destruction than the utilisation of the sulphur, followed by treatment of the cinders or residue for the recovery of very small proportions of a very valuable constituent, and where the compositions and charac-

ters of the ores dealt with are widely divergent, a new set of conditions are introduced.

In the first place, the oxidation and removal of the sulphur, arsenic, &c., must be complete and not merely partial; imperfectly decomposed pyrites is worse than unroasted for causing the mercury to flour, and thereby creating a loss of gold and amalgam. The conditions necessary to ensure sweet-roasting are a sufficient temperature, an abundant supply of fresh air, and an effective rabbling or distribution of the ore. Indications of perfect roasting are, that the hot ore emits neither sparks, fumes, nor odour on being stirred.

The effect of too little heat being employed will be not only that the ore is not sweetened, but that some of the freed gold may become coated with a film sufficient to repel the mercury. Too high a temperature, on the other hand, may cause a caking or fritting of the particles, and, in the absence of a full supply of air, a slag of mono-sulphide of iron may form, from which the recovery of the gold would be more difficult than before. Sometimes sand is introduced to prevent caking, and charcoal to promote decomposition, the carbon combining with the sulphur; but neither should be necessary, and the latter would be positively detrimental in presence of antimony or lead.

Now let us see what means have been adopted on the various gold fields to achieve the sweet-roasting of the auriferous sulphurets.

Foremost in point of popularity is the reverberatory furnace of multitudinous forms. Here the crushed ore is fed automatically or by hand (often the latter) into the upper portion of a slightly inclined chamber, and is gradually worked down the slope, by the periodical introduction of a rabbling tool through side doors in the chamber, always encountering a stream of hot gases from a fireplace at the bottom of the slope. The disengaged fumes from the ore are carried away into flues and condensers by the flow of products of combustion from the fireplace. The great and glaring faults of this system may be catalogued thus:—

(1) Excessive consumption of fuel.

(2) Employment of much labour.

(3) Slowness of operation, which is largely due to—

(4) The fact that only the surface of a body of ore is exposed to the oxidising influence, while—

(5) The current of "air" which is to effect the oxidation is first robbed of its oxygen to support the combustion of the fire in the fireplace, so that the oxidising current is chiefly composed of carbonic acid!

The practical result of all this blundering is that the operation costs 10*s.* to 20*s.* a ton for wages and 8*s.* to 15*s.* a ton for fuel, and the total expenses would not be covered by 1 oz. of gold per ton. But the efficiency may reach as high even as 98½ per cent.

A step in advance was the revolving cylinder. In this fault (5)

survives to the full extent; faults (1), (3), and (4) are moderated, while fault (2) is replaced by a new one, viz. the expenditure of power in causing the cylinder to revolve.

The rotating-bed furnaces perpetuate many of the errors of the revolving cylinders, but to Sergeant and Flude's belongs the merit of being the first to provide an independent (but intermittent) supply of heated fresh air for oxidising purposes, the ore being kept distinct from the products of combustion derived from the fire. Moreover, the inventors utilise the sulphurous acid evolved.

Next come the shaft furnaces, two forms of which are extensively used, each giving satisfaction in its particular range of application—the Gerstenhöfer in Europe and the Stetefeldt in America. These are really reverberatory furnaces in principle, only built vertically instead of horizontally.

Gerstenhöfer's furnace carries out to the full the principle of making the pyrites support its own combustion. The powdered ore falls down a shaft, its descent being delayed by a [illegible]mber of crossbars which break up the stream and help to [illegible]x-posure of every particle to the rising current of air [illegible] base of the shaft. When the furnace has once been heated [illegible] redness, no further fuel is needed to maintai[illegible] The [illegible] oxide generated is utilised for making [illegible] aci[illegible] of pyrites is the main object of the furnace, thoug[illegible] found [illegible] the tant sphere of usefulness in dealing wit[illegible] fines" at ci[illegible] works. From the gold-miner's point of vie[illegible] chief fault seems to be that the temperature is not sufficien[illegible] under control, and that there is frequently a sintering of the ore, which is checked by adding spent ore to the charge.

Stetefeldt's furnace was designed for chloridising silver ores. It consists of a plain shaft, down which the ore falls in a thin steady shower, encountering the heated vapours and products of combustion from fireplaces at the base, and currents of cold air admitted from the sides. This furnace has done excellent service in the silver industry and has a world-wide reputation, but is not without faults. Thus, the unimpeded fall of the ore renders its passage too rapid for complete oxidation to take place, added to which the gases from the fire mingle with the ore, and necessitate the admission of a large extra supply of oxygen, which, entering as cold air, reduces the temperature and compels an additional consumption of fuel. Hence the cost of roasting is greater than it should be, the labour reaching from 3*s.* to 4*s.* a ton, and the fuel from 2*s.* to 3*s.* 6*d.* a ton. Moreover, the sulphurous oxide cannot be utilised.

Sufficient has been said to show that all these furnaces leave much to be desired when dealing with auriferous sulphides. Their capacity is too small, their action is too slow and incomplete, they require too much manual labour, they consume too much fuel, they make no provision for the after-treatment of the cinders, and they render the operation too costly. One or more of these draw-

backs is present in every case. What, then, are the conditions which an ideal furnace should fulfil? Practically these:—

(*a*) *Regular* and *automatic feed* and *discharge.*
(*b*) *Self-supporting* combustion.
(*c*) *Utilisation* of *all* products.
(*d*) *Accessibility* for repairs.
(*e*) *Total* cost of *treatment* under 2*s*. (½ dwt.) per ton.

Given the first three conditions, the fifth will take care of itself. Indeed, judging from recent experiments on sulphides in bulk, I believe the cost may be reduced to less than 1*s*. a ton, in the case of clean ores rich in sulphur.

A sectional illustration of the furnace which bids fair to accomplish these ends is shown in Fig. 56. It is the invention of Mr. Charles J. Fauvel, who while cleverly adapting such good features as were to be found in existing furnaces, set himself to remedy their defects, with a result that is highly promising. As may be imagined, this result was not arrived at in a moment, nor is it to be supposed that finality is reached. Modifications and improvements in the details will no doubt be dictated by special circumstances of localities where the furnace is to be used; but taken as it stands, it is thoroughly sound in principle, and provides in a most practical manner for all reasonable conditions, as will be seen from the following description.

The fireplace A is constructed so that it will burn coal, coke, or wood. Its side walls are provided with small air-holes for the admission of an extra supply of atmospheric air, so as to ensure perfect combustion, thus saving a waste of fuel, and at the same time avoiding the possibility of any free carburetted hydrogen passing away into the flues, with a risk of causing explosions. The fire is so directed that its greatest heat is developed just where it is required, viz., under the lowest slab B of the oxidising tower C. The fireplace A is built in duplicate, thus giving a greater command of heat at starting, or whenever it may be needed.

The oxidising tower C, in which the oxidation of the sulphides, &c., is accomplished, consists of a square brick structure about 40 ft. high, fitted inside with a series of sloping slabs D made of firelump, and projecting alternately from opposite walls of the tower C by which they are supported.

These slabs D stretch diagonally across almost the entire width of the tower, so that whatever enters at the top of the tower must pass over the whole surface of each slab in rotation until it can escape at the bottom. Beneath each slab is carried a flue E direct from the fireplace A, and conveying the necessary heat to the under side of the slab D. These flues E have no connection with the interior F of the oxidising tower C, so that the products of combustion of the fuel in the fireplace never come into contact with the ore. This fact in itself is sufficient to distinguish Fauvel's furnace from all others of the kind, and to render it far superior to them from a metallurgical point of view.

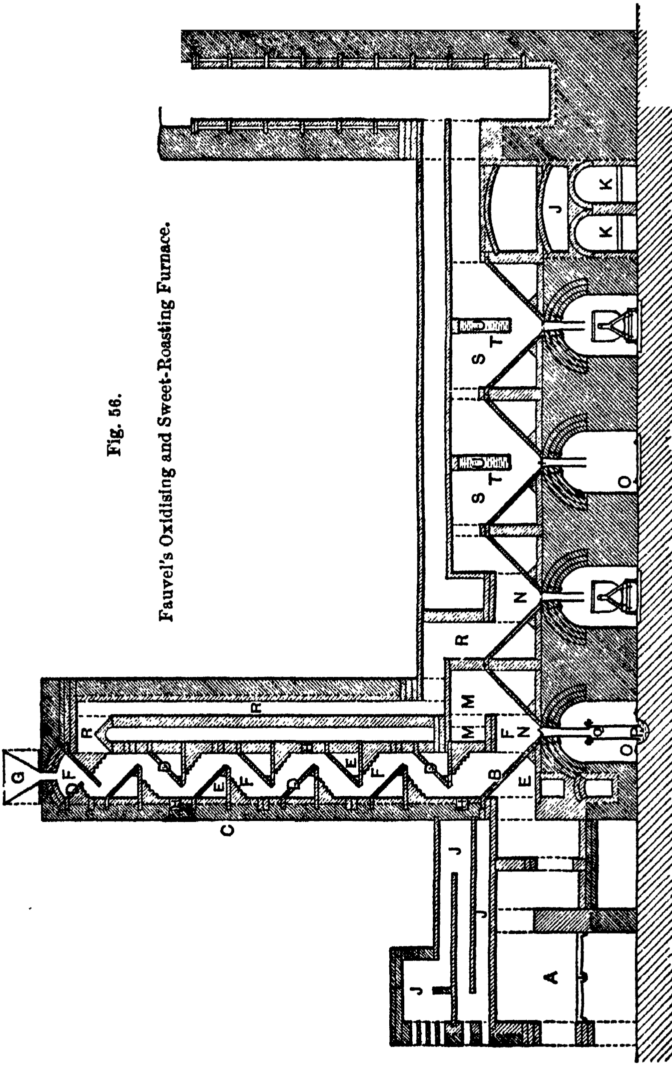


Fig. 56.

Fauvel's Oxidising and Sweet-Roasting Furnace.

At the top of the oxidising tower C is an automatic feeder G, consisting of a rifle-grooved cylinder working in a hopper, so arranged that the finely ground ore is distributed in a thin regular shower across the whole width of the tower. As the ore passes down the tower, it falls successively upon the hot sloping shelves D, rolling across them in a constant stream, and dropping from one to the next.

The angle and adjustment of the shelves D are such that the whole surface of each slab does its full share of the work, the ore particles being kept in a state of incandescence during the time they are in contact with the slabs.

The wear and tear inside the tower is reduced to a minimum by avoiding all ironwork in its internal construction, and by making the slabs self-supporting. As a further provision in case of accidental injury to or flaw in the slab, each is built in independently of all the others, and the inner and side walls of the tower consist of a series of brick arches H, so turned that by them any slab can be separately reached, removed, and replaced with the least possible inconvenience and cost, and without in any way disturbing the rest of the tower, or weakening the structure.

During the whole of their passage downwards through the tower, the ore particles encounter an abundant upward stream of hot air, which is provided by means of special chambers J, placed above the fireplace A and over a secondary fireplace K, built near the base of the chimney L. These air-heating chambers J are furnished with adjustable doors, so that the air supply can be regulated to suit the ore under treatment. This stream of heated air, kept free from the products of combustion in the fireplace, flows up through the oxidising tower F in such a manner that it meets the incandescent particles of falling ore, checking them in their descent, and scattering them in such a way that it is impossible for any particle to escape the complete oxidation and removal of its associated sulphur, arsenic, antimony, or tellurium compounds. This admission of pure hot air is another feature in which the Fauvel furnace is distinctly in advance of others, all the oxygen contained in the air being available for oxidising and sweetening the ore, instead of being largely consumed in completing the combustion of the gases from the fireplace A.

The first principles of sweet-roasting demand that the ore shall encounter a gradually rising temperature. For this reason, the topmost shelves in the tower have no heating flue beneath them, and hence are relatively cool.

On the other hand, the lowest shelves are in direct contact with the fullest heat from the fire as it leaves the fireplace. In addition, the stream of heated air enters at M, near the bottom of the tower, and helps both by its own heat and by perfecting the oxidation at that point, to raise the temperature to the highest degree just where its effect is needed. Moreover, the air is purest on meeting the ore as it approaches the completion of its oxidation; whereas

in other furnaces the oxidising power of the air admitted is all used up at an early stage, and thus the last traces of sulphur, &c., are only imperfectly removed. In the Fauvel furnace the ore encounters a gradually rising temperature combined with increasingly pure air, so that the culminating points of the heating and oxidation coincide, and mark the termination of the process. On these accounts the sweetening of the ore is done much more rapidly and efficiently than by other furnaces.

By the time the ore has passed through the oxidising tower F it is completely sweetened. In this state it falls into a settling pit N situated immediately beneath the tower. This pit may be of ordinary construction, or provided with trucks and rails O for facilitating the withdrawal of the roasted ore for further treatment.

This generally consists in wet amalgamation, after the ore has been spread on a cooling floor, entailing much labour, waste of time, and the risk of losing a portion of the gold. Another evil sometimes arising from the roasting process is that the little particles of gold become glazed, as it were, with a microscopic coating of iron oxide, sufficient to prevent that intimate contact with the mercury which is absolutely essential to success in catching the gold by amalgamation.

As water must play an important part in the final amalgamation, and the power of water as a vehicle for transporting finely ground material is familiar to all gold miners, the idea suggested itself that the cumbersome system of trucks and cooling floors might be advantageously replaced by a running stream of cold water. Acting upon this, Fauvel made a number of experiments on the effects of quenching the incandescent ore in a bath of cold water. The results surpassed all expectation. Each glowing particle as it falls into the water causes an instantaneous generation of steam, accompanied by a report as of a miniature explosion. At the same moment, any glaze or skin which may have formed on the particles is ruptured, and they are broken down to a remarkably fine state and rendered very brittle. So much is this the case that an arsenical pyrites, which had been crushed only to pass a 30-mesh sieve, was, after roasting and quenching, rendered an impalpable powder. The importance of this innovation can hardly be exaggerated. In the first place, exceedingly fine crushing is not necessary, and therefore the output of the mill can be very much increased. In the second place, the ore is reduced to such a microscopic size that there is no longer any room for atoms of gold to be locked up in it. Thirdly, the skin of oxide, which is so apt to coat the grains, is removed, and the gold is rendered clean and shining, so that the tiny specks of precious metal can, with a lens, be seen scattered through the mass, and are thus in a condition specially adapted to amalgamation.

The only precaution found to be necessary, in order to be sure of attaining this end, is that the water be kept in a turbulent state,

otherwise the bubbles of steam, generated by the falling atoms of ore, enable them to float and accumulate on the surface of the water, instead of undergoing immediate and complete immersion.

The practical outcome of these experiments is, that the oxidised and sweetened ore is by Fauvel's system made to fall direct from the oxidising tower into a constantly running stream of cold water P, kept in a state of agitation by the introduction of spray pipes Q near the point where the ore falls into the water. The particles are thus at the same moment cooled, broken down and transported by the stream to a series of settlers, where the heavier and valuable portions collect, and from which they are raised by elevators and delivered into suitable amalgamators, while the sludge or thin slime and surplus water run away to the waste dump. The consumption of water is no greater than in ordinary amalgamation.

It is a distinct feature of Fauvel's furnace, that the products of combustion from the fireplace (there is no smoke properly speaking) are from first to last kept away from contact with the ore. The passages E, provided for them are quite distinct, and are so arranged as to utilise all the heat generated, viz., in heating the shelves over which the ore runs, in maintaining the heat of all portions of the tower where it is needed, and in providing the supply of hot air. Finally, the products of combustion pass into the chimney L; near this chimney is a supplementary fireplace K, which may be used for generating chlorine gas, when dealing with silver ores, or to augment the draught.

The fumes of sulphur, arsenic, antimony, &c., generated by the heat encountered as the ore falls through the tower, flow upwards and become most dense on reaching the top of the tower.

This result is attained by the admission of a current of pure hot air at M, into the settling pit N at the bottom of the tower F. This air current serves the double purpose of aiding the oxidation, and conveying away the liberated fumes. These latter pass off at the top of the tower through an independent flue R, and on to a set of condensing chambers S, which are fitted with a series of exposed metal surfaces T, kept cold by a constantly renewed stream of water U. By these means, condensation of the sulphuric and other fumes is brought about in a rapid and effective manner, without contaminating the water. The result is a product which can be withdrawn simply and expeditiously by means of little trucks V made to run on rails O beneath the condensing chambers S. Thus the vapours admitted from the flues R through the condensing chambers S, into the chimney L, and finally escaping into the open air, are for the most part free from noxious properties

It will be seen that Fauvel's invention, which has been patented all over the world, is not simply an improved furnace for roasting pyrites, but is actually a complete process for treating refractory gold ores. Its simplicity and economy will soon bring it into favour, and it will doubtless become familiarly known as "fauvelising."

WIRE ROPES (*continued from p.* 80).

Uncoiling.—It is most important to prevent kinking, that the coil should be placed on a reel or turn-table, and the rope drawn off from the outside.

Attachments.—With improved solid wrought-iron shoes or sockets for capping, no rivets are required; where the latter are employed, damage to the wires inside the socket is the result.

Storing.—Wire ropes should be kept in a dry place, and laid upon timbers. They should also be oiled over occasionally. Much damage often results from corrosion through improper storage.

Preservation.—When ropes are exposed to the destructive action of mineral or acid waters, they should be made of galvanised wires, and of as large a gauge as possible. In all cases a protection is afforded by frequently lubricating them with a good grease, free from creosote, ammonia, acids, or other injurious admixture. It is of especial importance that any broken wires should be cut away, or what is better, that they be bent backwards and forwards until they break off short at the place where they disappear into the rope, otherwise the broken wires, in consequence of the pressure, are apt to damage the neighbouring ones in passing over the drum and sheaves, and in this way whole strands in a partly-worn rope are often destroyed.

Round Winding-rope Pulleys.—The groove should be quite smooth and sufficiently wide, so as not to pinch the rope. The pulleys should be regularly inspected, and if it is found that the rope has been working a false groove into the pulley, the groove should be turned to its former shape, which can be done by fixing a cross-beam to serve as a rest for the turning tool. The false groove seldom harms the rope that has made it, but quickly damages the new rope which takes the old one's place, and which, not being worn, is of a larger diameter than the old rope, and does not fit into the false groove, therefore it the more rapidly wears on the sharp edges formed by the false groove with the original groove.

Flat Winding-rope Drums and Pulleys.—The drum arms or horns should be placed so far apart that the rope has not more than about ¼ in. play between them. The inner edges of the horns should be well rounded off so as not to chafe the rope. The pulleys for flat ropes should have the grooves turned perfectly true and cylindrical, neither concave nor convex as belt pulleys are.

Cable-laid Wire Ropes.—These should be used where heavy weights have to be lifted occasionally, and where the winding barrel is necessarily of small diameter, such as for pit capstans, &c. As

Cable-laid Wire Ropes—continued.

they are not in constant use, it is essential that the wires should be galvanised so as to ensure the rope against the corrosive action of rust.

Lang's Lay Wire Ropes.—When wire ropes are constructed by the ordinary method, the friction surface is so comparatively small that the strands are worn only on the crowns. The wires retain their full size and strength at each side of the worn or weakened parts, causing them to give way, although the greater portion of the wires have been subjected to no wear whatever. In the construction of Lang's Lay ropes, there is a much larger wearing surface, which almost entirely removes the cause of the wires breaking on the crown of the strand, and as the working of the ropes around pulleys, drums, &c., bends the wires in an oblique direction, we secure by this system the greatest possible amount of wear from the wires before fracture, as they will not break before they are so much reduced in strength as to be too weak throughout for the work. The wires in the strands of the ropes on Lang's Lay principle have a very much longer bearing one against another than in the old system, and thereby prevent the great injury which results from the wires in the adjoining strands cutting into each other.

Wire Driving Ropes.—These are coming largely into use for transmission of power, and afford the cheapest means for this purpose for long or short distances. The loss of power amounts at the outside to 1 per cent. per 100 yd.

Table 148.—*Flat Wire*

Sizes.		Weights per fath.	Mild Steel (Siemens-Martin.			Improved Patent Steel.			Best Plough Steel.			Extra Plough Steel.		
			Sizes.		Breaking strain.	Sizes.		Breaking strain.	Sizes.		Breaking strain.	Sizes.		Breaking strain.
Width.	Thickness.		Width.	Thickness.		Width.	Thickness.		Width.	Thickness.		Width.	Thickness.	
in.	in.	lb.	in.	in.	ton.	in.	in.	tons.	in.	in.	tons.	in.	in.	tons.
2¼	7/16	9	2¼	7/16	15	2¼	7/16	26	2¼	7/16	33	2¼	7/16	39
2⅜	7/16	10	2⅜	7/16	17	2⅜	7/16	29	2⅜	7/16	36	2⅜	7/16	43
2½	½	12	2½	½	20	2½	½	35	2½	½	44	2½	½	52
2¾	½	14	2¾	½	23	2¾	½	41	2¾	½	51	2¾	½	61
3	9/16	16	3	9/16	27	3	9/16	47	3	9/16	59	3	9/16	70
3¼	⅝	18	3¼	⅝	30	3¼	⅝	53	3¼	⅝	66	3¼	⅝	79
3½	11/16	20	3½	11/16	33	3½	11/16	59	3½	11/16	73	3½	11/16	88
3¾	¾	23	3¾	¾	38	3¾	¾	68	3¾	¾	85	3¾	¾	102
4	¾	26	4	¾	43	4	¾	77	4	¾	96	4	¾	115
4¼	13/16	29	4¼	13/16	48	4¼	13/16	86	4¼	13/16	108	4¼	13/16	129
4½	⅞	33	4½	⅞	53	4½	⅞	98	4½	⅞	123	4½	⅞	147
4¾	15/16	36	4¾	15/16	60	4¾	15/16	107	4¾	15/16	134	4¾	15/16	160
5	1	39	5	1	65	5	1	116	5	1	145	5	1	174
5¼	1 1/16	44	5¼	1 1/16	74	5¼	1 1/16	131	5¼	1 1/16	164	5¼	1 1/16	196
5½	1⅛	48	5½	1⅛	81	5½	1⅛	143	5½	1⅛	179	5½	1⅛	214
5¾	1 3/16	52	5¾	1 3/16	87	5¾	1 3/16	155	5¾	1 3/16	194	5¾	1 3/16	232
6	1¼	57	6	1¼	96	6	1¼	170	6	1¼	213	6	1¼	255

Note.—The weights per fathom for flat wire ropes are given for hemp core in each strand; for wire cores, add about 1/9 to the given weights.

Working Loads for Round and Flat Wire Ropes.—For vertical winding at a

brea[king strain. For inclines, the working strain]
to gradient, and friction, &c., should be added.

Compound Round Wire Ropes, 2*s.* 6*d.* to 5*s.* per cwt. extra, according to the number of wires in the installation.

Table 149.—*Cage Guide Ropes or Conductors.*

Circumference, inches ..	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½
Diameter, inches	15/16	1 1/32	1⅛	1 3/16	1¼	1 11/32	1 7/16	1½	1 19/32	1 11/16	1¾
Weight per fathom, lb. ..	11¾	13½	15¾	18¼	21	23½	26½	29½	32¾	36	39¾

Table 150.—*Galvanised Wire Signal Strand.*

Number	00	0	1	2	3	4	5	6	7	8	9	10
Diameter, inches ..	11/32	5/16	19/64	9/32	¼	15/64	7/32	3/16	11/64	5/32	9/64	⅛
7 Ply., W. G. No. ..	11	11½	12	13	13½	14	15	16	17	17½	18	18½
Length per cwt., yd...	150	170	190	240	280	310	380	480	640	750	850	1050

Table 151.—*Round Wire Ropes.*

Sizes.		Weights per Fathom. 6 Strands.		Mild Steel (Siemens-Martin).		Improved Patent Steel.		Best Plough Steel.		Extra Plough Steel.	
Cir.	Dia.	7 Wires.	6 Wires.	Cir	Breaking Strain.	Cir.	Breaking Strain.	Cir.	Breaking Strain.	Cir.	Breaking Strain.
in.	in.	lb.	lb.	in.	tons.	in.	tons.	in.	tons.	in.	tons.
1	5/16	1·0	0·9	1	1½	1	2¾	1	3½	1	4
1⅛	11/32	1·2	1·1	1⅛	2	1⅛	3½	1⅛	4¼	1⅛	5¼
1¼	⅜	1·5	1·3	1¼	2⅝	1¼	4¼	1¼	5¼	1¼	6¼
1⅜	13/32	1·8	1·6	1⅜	3	1⅜	5¼	1⅜	6½	1⅜	7¼
1½	15/32	2·1	1·9	1½	3½	1½	6¼	1½	7¾	1½	9¼
1⅝	½	2·5	2·3	1⅝	4	1⅝	7¼	1⅝	9	1⅝	10¼
1¾	9/16	2·9	2·6	1¾	4¾	1¾	8½	1¾	10½	1¾	12¾
1⅞	19/32	3·3	3·0	1⅞	5¼	1⅞	9½	1⅞	11¾	1⅞	14¼
2	⅝	3·8	3·5	2	6¼	2	11	2	13¾	2	16½
2⅛	11/16	4·3	4·0	2⅛	7	2⅛	12½	2⅛	15½	2⅛	18¾
2¼	23/32	4·8	4·4	2¼	7¾	2¼	14	2¼	17½	2¼	21
2⅜	¾	5·3	4·9	2⅜	8¾	2⅜	15½	2⅜	19½	2⅜	22½
2½	25/32	5·9	5·5	2½	9¾	2½	17¼	2½	21½	2½	25¾
2⅝	27/32	6·6	6·0	2⅝	10¾	2⅝	19¼	2⅝	24	2⅝	28¾
2¾	⅞	7·1	6·6	2¾	11¾	2¾	20¾	2¾	25¾	2¾	31
2⅞	29/32	7·8	7·2	2⅞	12¾	2⅞	22¾	2⅞	28¼	2⅞	34
3	15/16	8·5	7·8	3	14	3	25	3	31¼	3	37½
3⅛	1	9·2	8·5	3⅛	15	3⅛	27	3⅛	33¾	3⅛	40½
3¼	1 1/32	9·9	9·1	3¼	16¼	3¼	29	3¼	36¼	3¼	43½
3⅜	1 1/16	10·7	9·9	3⅜	17¾	3⅜	31½	3⅜	39¼	3⅜	47¼
3½	1⅛	11·5	10·6	3½	19	3½	33¾	3½	42	3½	50½
3⅝	1 5/32	12·3	11·4	3⅝	20¼	3⅝	36	3⅝	45	3⅝	54
3¾	1 3/16	13·2	12·2	3¾	21¾	3¾	38¾	3¾	48¼	3¾	58
3⅞	1 7/32	14·1	13·0	3⅞	23¼	3⅞	41¼	3⅞	51¾	3⅞	62¼
4	1¼	15·0	13·9	4	24¾	4	44	4	55	4	66
4⅛	1 5/16	16·0	14·8	4⅛	26½	4⅛	47	4⅛	58¾	4⅛	70¼
4¼	1 11/32	17·0	15·7	4¼	28⅛	4¼	50	4¼	62½	4¼	75
4⅜	1⅜	18·0	16·6	4⅜	29¾	4⅜	53	4⅜	66¼	4⅜	79½
4½	1 7/16	19·0	17·6	4½	31¼	4½	56	4½	70	4½	84
4¾	1½	21·0	19·6	4¾	35	4¾	62¼	4¾	77¾	4¾	93¼
4⅞	1 17/32	22·0	20·6	4⅞	36¼	4⅞	64½	4⅞	80½	4⅞	96¾
5	1 19/32	23·5	21·7	5	39	5	69	5	86¼	5	103½
5¼	1 11/16	26·0	24·0	5¼	43	5¼	76½	5¼	95½	5¼	114¾
5½	1¾	28·5	26·3	5½	47	5½	83¾	5½	104½	5½	125¼
5¾	1 13/16	31·1	28·7	5¾	51½	5¾	91½	5¾	114¼	5¾	137¼
6	1 29/32	34·0	31·3	6	56¼	6	100	6	125	6	150

Note.—For wire core in centre of ropes, add 1/7 to the weights given for 6 strands of 7 wires.

Working Loads.—See remarks on p. 376.

DRILLING (*continued from p* 124).

The Ingersoll-Sergeant Rock Drill.

The advantages of a combination of inventions are forcibly exemplified in the new Ingersoll-Sergeant Rock Drill. Until recently the Ingersoll drill and the Sergeant drill were manufactured by two separate companies, although the essential points in each drill had been designed by one man, Mr. Henry C. Sergeant. One of these drills, which he called the Eclipse, belonged to the Ingersoll Rock Drill Co., and the other, the later production, belonged to the Sergeant Drill Co. This machine embodied the results of an exceptionally long and varied experience in the manufacture of rock drills. It was, however, soon apparent, that to produce the most effective machine without infringement of patents, it would be necessary to amalgamate the two companies, and this being done, under the title of the Ingersoll-Sergeant Drill Co., a drill is now produced for which it may be justly claimed that it embraces in its design the best features of the older and the newer types of rock-drilling mechanism.

In order to introduce this machine into Great Britain and the continent of Europe, the Ingersoll-Sergeant Drill Co. has opened an office at 114A, Queen Victoria Street, London, where a stock of complete drills and duplicate parts is kept ready for use.

The object of the inventor has been to design a drill capable of striking a hard and effective blow and to construct it in such a way that it will resist the effects of rough work during long periods of use. The combination has also the further advantages obtained in simplicity and strength of construction, fewness of moving parts, and reduction of violent shocks to other parts than the piston. The new machine contains an independent valve operated through an auxiliary valve. This important point together with its great cutting capacity when used on hard rock have formed the two most distinctive features of the Sergeant drill, and they are now to be had in conjunction with the well-known and approved features of the Ingersoll. The Ingersoll-Sergeant strikes an uncushioned blow, and every blow that is struck is made with full pressure and with cylinder clear in front. This applies as much to the short quick strokes with which work may be commenced, as to the longer strokes when the drill is deeper in the rock. The auxiliary valve, which is operated by the shoulders of the piston, moves lightly in the arc of a circle, and cannot by any possibility become deranged, its wear being uniform and its action automatic, while in itself it is a

Ingersoll-Sergeant Drill—continued.
simple piece of steel of suitable shape, without any parts to break. The rotating device is equally simple and effective, and has a release movement, a feature we believe possessed by no other drill in the world, which prevents the twisting of the spiral bar, or breaking of pawls and ratchets; thus, when a hard blow is struck upon an uneven surface, there can be no danger of breaking through a tendency to rotate in the wrong direction; the springs, which are provided for cushioning the blow of the piston, being also made use of for controlling and assisting the rotation. There are other improvements comprising the ease with which long or short strokes are obtained by varying the feed; and the absence of stuffing boxes where compressed air is used is another important feature in this machine.

The Ingersoll-Sergeant Cold Air Compressor.

The latest improvement in air-compressing machinery is represented by the Ingersoll-Sergeant cold air compressor. No water is admitted in the air cylinder, but the most thorough cooling is effected by contact with cold metal surfaces. The piston inlet valve is operated by the natural laws of momentum and without springs or levers. The engine is driven either by steam, or through a belt or gearing by water power or electricity. The special advantages and most important features of the Ingersoll-Sergeant piston inlet cold air cylinder are as follow:—The free air, before admission to the cylinder, is under thorough control, and may be taken from that point which is the most favourable in its dryness, reduced temperature, and freedom from dust and other foreign matter. The admission of free air being through a single tube creates a constant and uniform draught of air in one direction only, thus filling the cylinder at each stroke with air at atmospheric pressure. The air inlet valves are large metallic rings which are not operated by springs, but which open and close by the natural momentum given to the valve by the movement of the piston. When the piston is moving in one direction, the ring valve on that face of the piston which is towards the direction of movement is closed, while that on the other face is open. This is exactly as it should be in order to discharge the compressed air from one end of the cylinder while taking in the free air at the other. The position of each valve is almost instantaneously reversed at the point when the stroke is reversed. This change in position takes place without springs or other influence than the natural momentum of a piece of metal which is carried in one direction and is instantly reversed.

The large ring air inlet valves which serve to admit the air are said to be practically indestructible. These valves admit of a large area of inlet with but a small throw of valve, thus quickly opening a large supply port, and enabling a compressor to run at high

Cold Air Compressor—continued.
speed without a reduction of efficiency, and with safety to the quick-moving parts. There being no inlet valves in the heads of the air cylinder, the space otherwise occupied by these valves is filled with cold water, thus presenting a cooling surface to the compressed air near the end of the stroke when the air is hottest. We have here all the advantages of cooling by water injection, without the disadvantages incident upon bad water, and the necessity of moving a body of water back and forth in the cylinder. Clearance spaces are reduced to a minimum. There are no countersunk spaces in the cylinder heads for inlet valves, but there is a single annular space to take the face of the large ring inlet valve. The valve covers this space at the end of each stroke so that there is no dead space. The air inlet pipe which extends through the cylinder-head serves as a bearing and support for the piston, thus ensuring the minimum wear in the air cylinder, and a perfect uniformity of such wear as must take place in every engine. This is said to be the only air compressor made with a device which unloads the engine automatically.

RIVER MINING.

Dredging (continued from p. 180).

Ball's Ejector Dredge for Mining Gold, Tin, Diamonds, &c., in rivers and placers.

The most recent dredger bearing that name combines several of the features of the previous suction dredgers of the same builder (Charles Ball, C.E., 37, Lombard Street, E.C.), with some improvements which practice has shown to be essential.

The main features are:

1. That the material dredged does not go through the machinery as in ordinary suction dredgers, thereby saving all wear and tear caused by it, and enabling much coarser material and bigger stones to pass through a plant of a given size than was possible formerly.

2. That all compacted and hardened material is dug up and dispersed practically into the very nozzle of the suction apparatus —thereby preventing the loss of gold which occurs when it is attempted to stir up the material by rakes, revolving cutters, &c., in the current of a river, especially if at all rapid.

3. That it is assisted by an irresistible searcher, which goes right into cracks and fissures in the bed-rock, where often the gold is most thickly gathered, and pulls it out thereof to throw it into the suction nozzle—so that the loss of gold sometimes so great which occurs under these circumstances is entirely avoided.

4. The apparatus is even more simple than in the former Ball machines, and the cost and liability to repairs are both much diminished.

The results are obtained by the following means:—

A specially-built steam pump, worked from a small boiler, throws a stream of water, at very high pressure, into a dredging pipe in an ascending direction—this pipe is bent, after receiving this jet of water, so as to reach the bottom to be dredged—a branch, or several of them, got from where the high-pressure water enters the dredging-pipe, are brought in front of the nozzle on the ground, preceding it by a few inches.

These jets, under a head of some 300 ft. pressure or more, if required, tear up and rip the ground right into the nozzle, in which a violent sucking action is induced by the main jet entering above, as described previously.

These same small jets are the searchers which, with a flexibility that no machinery could possess, enter, ransack, and clear out of gold every crack and crevice in the bed-rock, even to a depth of several feet.

The material, with the water bringing it up, is delivered in a

Dredging—continued.
gentle and regular stream at the top of the suction-pipe on to any sluice, or other preferred gold-saving apparatus.

The machinery can all be reduced to parts weighing under 120 lb., an immense advantage in case of difficulties of carriage. The cost of a plant capable of dealing with 4-in. stones, and doing some 10 tons of sand and gravels per hour, all complete, with improved and very efficient set of steel sluice boxes, is about 350*l.* to 400*l.*

A large plant on this system has lifted 2000 tons a day to large sluicing boxes.

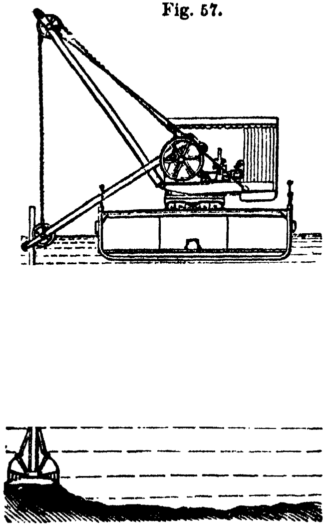
It is essentially the machinery for prospecting on an efficient scale rivers, lagoons, &c.

The "Cockburn" Dredger for Hard Materials.

This machine has been designed by Cockburn, Phillips, and Montgomery, of 50, Queen Anne's Gate, Westminster, S.W., with the object of providing a crane dredger that will excavate material which the ordinary single and double chain grab dredgers will not touch.

In the ordinary form of crane dredger, the only force available for closing the grab is that which, if applied to a sufficient extent, will eventually raise it off the ground, and consequently its resistance to being lifted—*i.e.*, its dead weight—is the utmost limit of the closing power that can be applied.

Fig. 57.



"Cockburn" Dredger.

It is obvious that the harder the material to be dredged, the greater the pull required on the chain to close the grab, and as the pull on the chain increases, so the weight of the grab on the ground will decrease. Thus there is less available weight to cause the grab to penetrate in dealing with hard material than there would be with soft.

In the dredger shown in Fig. 57, an arrangement is provided by which the force applied for closing the grab does not tend to raise it off the ground; consequently, when the grab is dropped, and the points or blades sink several inches into the ground, any requisite amount of force can be applied to close the jaws on the material without the possibility of the jaws slipping up, and merely scraping

Dredging—continued.
over the top of the ground. It is therefore plain that this dredger will excavate any material into which the points or blades of the jaws will sink several inches when the grab is dropped into it.

As the grabs weigh from 35 cwt. to 55 cwt., according to size, it is not difficult to form an idea of the immense hardness that material would have to possess before this dredger would fail to excavate it.

The closing of the grab is effected by a chain secured to the top of the tube, led under a guide pulley to the jib head, round a snatch block or monkey, over a second guide pulley, and finally taken round and secured to an ordinary windlass barrel in the grab frame. A chain is attached to the snatch block or monkey, and led to the derrick barrel of the crane. When this barrel is revolved, the grab is opened or closed at will in any position.

In dredging cranes which are fitted with a long pole or tube fixed into the grab, and working through the head of the crane jib, the depth to which the dredger will work is limited by the greatest length of pole or tube that can be used in practice with safety and consistently with its strength as a column. This limit is reached in a pole or tube about 30 ft. in length, so that, allowing the jib head of a crane dredger to be 18 ft. above water line, and the total length of pole and grab to be 35 ft., the limit is reached at 15 ft. dredge.

To provide against this, a movable or falling jib is pivoted to the frame of the crane, carrying the two guide sheaves for the closing chain at its outer end. By this means a depth of 32 ft. below water line can be reached with a length of pole or tube well within the range of practice.

An additional advantage is obtained from the falling jib in the case of dredging where either waves or a swell are to be met with. The movable jib forms a hinged connection between the grab and the crane, so that any rise or fall of the barge carrying the dredger is taken up by the movable jib, and does not affect the grab, nor interfere with the closing of it.

The illustration is from a machine arranged to dredge to a depth of 25 ft., and manufactured by Grafton and Co., of Bedford, for the patentees.

The machine is made in two sizes:

$\frac{3}{4}$ yd. grab and	7	ton crane	to dredge to	25 ft.
1 „ „	10	„	„	32 ft.

For depth of dredge to 15 ft. the falling jib is not required.

Prices:—

To excavate 450 tons of hard material a day	775*l*.
„ 600 „ „ „ „	950*l*.

ORE DRESSING.

(Continued from p. 187.)

In order to obtain the most satisfactory results in dressing ores, great care must be taken in adapting the arrangement of machinery to the requirements of each case, and in carefully selecting the most suitable machines.

By following out a system of continuous concentration, aided by improved labour-saving appliances, particularly in the slimes department, and by observing suitable methods for minimising the production of slimes in crushing and separating, better results are obtained with less waste, and the cost of dressing is greatly decreased in all cases.

Lührig's Compound Vanner.

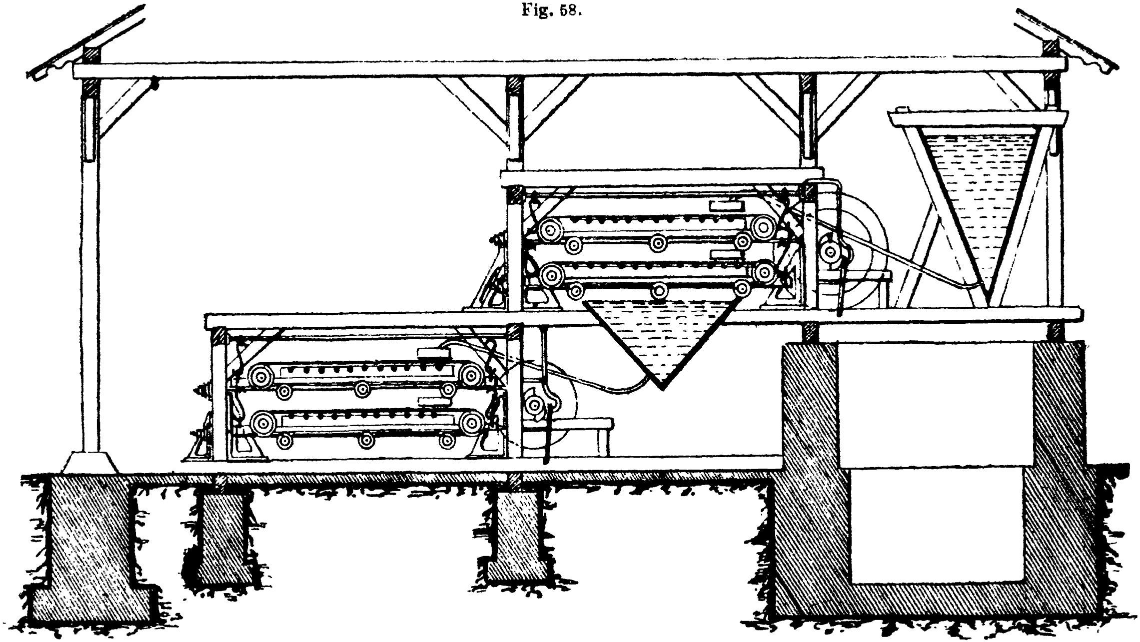
Quite remarkable, among the various recent improvements in ore-dressing plant, is the "Compound Vanner," invented by Lührig, whose success in coal-cleaning machinery is familiar. This novel vanner demands special mention for its self-acting qualities, and for its very successful treatment of slimes of the most complex character.

The striking feature of the Lührig vanner, as will be seen by Fig. 58, is the combination of three, four, or six (according to the nature of the ore) single tables of an improved construction, arranged in such a way as to allow of automatically feeding the "middle products" (or not yet sufficiently clean products) from the upper tables on to the lower tables. By this subsequent treatment of the middle products on the same machine, high concentrates are obtained without requiring manual labour or incurring loss of mineral.

The single table consists in the main of a travelling band, with adjustable lateral inclination, suspended from a frame receiving an end-shake, which, combined with the action of a spray-pipe extending diagonally across the table, effects the separation of the various minerals in the pulp, according to their specific weights. These various products are washed off by the spray into receptacles in front of the table. The material is fed on to the table by a siphon discharge from a hydraulic classifier.

The advantages of the single table over others consist, firstly, in the circumstance that *one* clean product is always obtained in one operation; and, secondly, any number of grades of concentrates of different ores may be obtained on one table, and the degree of concentration, as well as the percentage of mineral left in the tailings, be adjusted according to wish. The intermediate grades

Fig. 58.



Lührig's Compound Vanner.

Lührig's Compound Vanner—continued.
would then be made to yield higher concentrates by the lower tables of the compound vanner, as described before.

One compound vanner will treat about 9 tons per day of 10 hours, giving absolutely clean tailings, besides separating the various minerals contained in the ore, one from the other. It has been proved to give excellent results in treating slimes of lead and blende ores containing iron or copper pyrites, or spathic iron; and it is particularly well adapted for dealing with tin and copper ores, avoiding all the handling now so frequently necessary in consequence of the use of imperfect machines, such as buddles, &c.

In dressing auriferous ores containing a percentage of pyrites, this vanner does closer work with less cost than any other machine, and it has been proved that it will pay well in many cases to employ it on old tailings containing less than 4 dwt. of gold and 4 dwt. of silver to the ton.

The manufacture and sale of these machines in England, America, and the Colonies are in the hands of the Lührig Coal and Ore Dressing Appliances, Limited, 32, Victoria Street, Westminster, S.W.

GLOSSARY.

Abattis (Leicester), cross packing of branches or rough wood, to keep roads open for ventilation.
Abbruch (Germ.), ore broken off the vein.
Abendort (Germ.), western end of a mine.
Abendschicht (Germ.), afternoon shift.
Abendstoss (Germ.), western end of a mine
Abflanherd (Germ.), buddle.
Abfüllen (Germ.), to win a good body of ore.
Abkomniss (Germ.), junction of main lode and tributary.
Abra (Span.), fissure in a lode.
Abronziado (Span.), copper sulphides.
Abstrich (Germ.), the mass of black litharge appearing on the bath of work-lead early in cupelling.
Abtheilung (Germ.), a defined district of a mine under care of a deputy.
Abzug (Germ.), the first scum appearing (before *abstrich*) on molten lead.
Accompt (Corn.), settling day or place.
Achicar (Span.), to decrease water in a mine.
Acreage rent (Eng.), royalty or rent for working minerals.
Addlings (N. Eng.), earnings.
Ademar (Span.), to timber.
Ademador (Span.), mine carpenter.
Adit, a slightly rising tunnel driven into a mine from daylight, and used for access, transport, and drainage.
Adobe (Span.), sun-dried brick.
Adventurers, original prospectors.
After-damp, poisonous gas resulting from explosions of fire-damp chiefly carbonic acid.
Agitator (W. Amer.), settler.
Ahondar (Span.), to sink.
Air-box, wooden tubes, 9–15 ft. long, for ventilating headings or sinkings.
Air-course, ventilation channels.
Air-crossing, a bridge carrying one air-course across another
Air-end way, ventilation levels run parallel with main level.
Air-gate (Midlands), ventilation ways.
Air-head (Staff.), ventilation ways.
Airless end, unventilated extremity of a stall in long-wall workings.
Air-level, an old level used for ventilating.
Air-slit (Yorks.), a short head between other air-heads.
Air-stack, ventilating chimney.

Aitch-piece, parts of a pump in which the valves are fixed.
Albañil (Span.), mason.
Albayalde (Span.), white lead.
Alberti furnace, a continuous reverberatory for mercury ores.
Alcam (Wales), tin.
Alive (Corn.), productive.
Alligator (Amer.), rock breaker.
Alloy, compound metal.
Alluvium, gravel, sand, and mud deposited by streams.
Almadeneta (Span.), stamp-head.
Almagre (Span.), red ochre.
Aludel (Span.), earthen condenser for mercury.
Amalgamation, absorption of gold and silver by mercury.
Anemometer, wind measurer.
Anthracite, hard, very pure coal.
Apex (Amer.), end or edge of vein nearest surface.
Apolvillados (Span.), superior ores.
Appolt oven, a coke oven.
Aprons (Amer.), battery copper plates.
Arch (Corn.), portion of lode left standing to support hanging wall, or because too poor.
Arenaceous, sandy.
Arends tap, an inverted siphon for drawing molten lead from crucible or furnace.
Arenillos (Span.), refuse earth.
Argentiferous, silver-bearing.
Argillaceous, clayey.
Arian (Wales), silver.
Arm, the inclined leg of a set of timber.
Arrage (N. Eng.), sharp corner.
Arrastra (Span.), an amalgamating mill.
—— *de cuchara* (—), spoon arrastra.
—— *de marca* (—), large arrastra.
—— *de mula* (—), mule-power arrastra.
Arrastrar (Span.), union of veins.
Aspirail (Fr.), opening for ventilation.
Assessment work (W. Amer.), the annual work necessary to hold a claim.
Astel, overhead boarding in a gallery.
Astyllen (Corn.), small dam in an adit; partition between ore and deads on grass.
Atierres (Span.), refuse rock.
Atizador (Span.), furnace man.
Attle (Corn.), refuse rock.
Auger-stem, bar to which a drilling bit is attached.
Auget, priming tube.
Aur (Wales), gold.
Auriferous, gold-bearing.
Ausscharen (Germ.), junction of lodes.

Auszimmern (Germ.), timbering.
Average produce (Corn.), percentage of fine copper in ore.
Average standard (Corn.), price of pure copper in ore.
Aviador (Span.), he who provides the capital to work a mine.
Azogue (Span.), mercury.
Azogueria (Span.), amalgamating works.
Azoguero (Span.), amalgamator.
Azogues (Span.), inferior ores.

Back (Corn.), lode lying between adit and surface.
Back-casing, temporary shaft-lining of dry-laid bricks.
Back-end (N. Eng.), the last portion of a judd.
Backing, timbers let into notches in the rock across the top of a level.
Backing deals (N. Eng.), vertical planks behind the curbs in a shaft.
Back-shift, afternoon shift.
Back-skin (N. Eng.), a leather jacket for wet workings.
Bait, provisions.
Bal (Corn.), a mine.
Balance-bob, a heavy counterpoise to pump-rods.
Balk (N. Eng.), a hitch causing a nip.
Balland (Derb.), pulverulent lead ore.
Bancos (Span.), rocks disturbing a lode.
Band (N. Eng.), stone interstratified with coal.
Bank, (1) surface at pit's mouth; (2) deposit worked above water level; (3) coal face.
Bank claim (Aust.), mining right on bank of stream.
Bank right (Aust.), right to divert water to bank claim.
Baño (Span.), excess of mercury used in torta.
Bar, (1) ridge crossing lode or stream; (2) drilling-rod.
Bar diggings (W. Amer.), auriferous claims on shallow streams.
Bargain, portion of mine worked by a gang on contract.
Barilla (Span.), grains of native copper disseminated through ores.
Barmaster (Derb.), mine manager, agent, and engineer.
Barmote (Derb.), mining court.
Barrel-work (N. Amer.), native copper that can be hand-sorted ready for smelting.
Barrow (Corn.), a dump.
Basque, crucible or furnace lining.
Bass (Derb.), indurated clay.
Basset, an outcrop.
Batea (Span.), a bowl for separating metal from refuse.
Batt (Derb.), indurated clay.
Beans (N. Eng.), small coals.
Bean-shot, copper granulated by pouring into hot water.
Beat (Corn.), to cut away a lode.
Bed-claim (Aust.), a mining-claim on bed of stream.
Bed-rock, solid rock underlying alluvial.
Bede, miners' pickaxe.

Belly-helve, forge hammer lifted by cam.
Ben (Corn.), productive.
Benching up (N. Eng.), working on top of coal.
Bend (Derb.), indurated clay.
Benheyl (Corn.), flowing tin stream.
Biche, a hollow-ended tool for recovering boring rods.
Bind (Derb.), indurated clay.
Binder (Corn.), mine carpenter.
Bing (N. Eng.), 8 cwt. of ore.
Bing-hole (Derb.), an ore-shoot.
Bing-ore (Derb.), lead ore in lumps.
Bing-tale (N. Eng.), ore given to the miner for his labour.
Black band, an earthy carbonate of iron found in coal-beds.
Black copper, impure smelted copper.
Black damp, carbonic acid gas.
Black ends, refuse coke.
Black flux, charcoal and potassium carbonate.
Black jack, zinc blende.
Black lead, graphite.
Black sand (Aust.), dark minerals found with alluvial gold.
Black tin (Corn.), dressed tin ore.
Blanch, lead ore mixed with other minerals.
Blanched copper, copper alloyed with arsenic.
Blanket strake (Aust.), sloping tables or sluices lined with baize for catching gold.
Blick (Germ.), iridescence on gold and silver at end of cupelling.
Blind creek (Aust.), dry watercourse.
Blind level, (1) an incomplete level; (2) a drainage level.
Bloat, a hammer swelled at the eye.
Block claim (Aust.), a square mining claim.
Block tin, cast tin.
Blocking out (Aust.), washing gold gravel in sections.
Bloomary, a forge for making wrought iron.
Blossom, the decomposed outcrop of a vein or coal-bed.
Blower (N. Eng.), an outrush of gas.
Blue-billy, residue of copper pyrites after roasting with salt.
Blue elvan (Corn.), greenstone.
Blue-john (Derb.), fluorspar.
Blue lead (W. Amer.), a blue-stained stratum of gravel of great extent and richness.
Blue peach (Corn.), a slate-blue fine-grained schorl.
Blue stone, copper sulphate.
Bob (Corn.), triangular frame transmitting power from engine to pump-rods.
Boca (Span.), mine mouth.
Bocamma (Span.), mine mouth.
Bog iron ore, loose earthy brown hematite recently formed in swampy ground.

Bollos (Span.), triangular blocks of amalgam.
Bolsa (Span.), small bunch of ore.
Bonanza (Span.), body of rich ore.
Bone, slaty matter in coal seams.
Bonnet, the roof of a cage.
Bonney (Corn.), an isolated body of ore.
Bouze, undressed lead ore.
Booming, removing gravel by sudden outlets of pent-up water.
Borrasca (Span.), unprofitable ore.
Bort, amorphous dark diamond.
Bottoms, impure copper alloy below the matt in smelting.
Bounds (Corn.), a tract of tin ground.
Bout (Derb.), 24 dishes of lead ore.
Bowke (Staff.), small wooden box for hauling ironstone underground
Bowse (Derb.), lead ore as cut from the lode.
Box-bill, tool for recovering boring-rods.
Brace (Corn.), buildings at pit mouth.
Braize (Amer.) charcoal dust.
Brake-sieve, hand jigger.
Brances, iron pyrites in coal.
Branch, small vein shooting off from main lode.
Brasses, iron pyrites in coal.
Brat, a thin bed of coal mixed with pyrites or limestone.
Brattice, a lining or partition.
Brazil (N. Eng.), iron pyrites in coal.
Breeze, small coke.
Brettis (Derb.), a timber crib filled with slack.
Broaching bit, a tool for re-opening bore-hole which has partially closed by swelling of the walls.
Brob, a spike to prevent timber slipping.
Broil (Corn.), traces of a vein in loose matter.
Brooch (Corn.), mixed ores.
Brood (Corn.), heavy waste from tin and copper ores.
Brownspar, ferruginous dolomite.
Browse, imperfectly smelted ore mixed with cinder and clay.
Bryle (Corn.), traces of a vein in loose matter.
Bucking, breaking down ore with a very broad hammer ready for jigging.
Buddle, an inclined stationary or revolving platform, on which ores are dressed.
Buitron (Span.), a silver furnace.
Bulkhead, (1) a tight partition, or stopping ; (2) the end of a flume carrying water for hydraulicing.
Bulldog, furnace lining.
Bully, a miners' hammer.
Bunch, a small rich ore body.
Bunding, a staging in a level for carrying débris.
Bunney, a nest of ore not lying in a regular vein.
Burden, earth overlying a bed of useful mineral.

Belly-helve, forge hammer lifted by cam.
Ben (Corn.), productive.
Benching up (N. Eng.), working on top of coal.
Bend (Derb.), indurated clay.
Benheyl (Corn.), flowing tin stream.
Biche, a hollow-ended tool for recovering boring rods.
Bind (Derb.), indurated clay.
Binder (Corn.), mine carpenter.
Bing (N. Eng.), 8 cwt. of ore.
Bing-hole (Derb.), an ore-shoot.
Bing-ore (Derb.), lead ore in lumps.
Bing-tale (N. Eng.), ore given to the miner for his labour.
Black band, an earthy carbonate of iron found in coal-beds.
Black copper, impure smelted copper.
Black damp, carbonic acid gas.
Black ends, refuse coke.
Black flux, charcoal and potassium carbonate.
Black jack, zinc blende.
Black lead, graphite.
Black sand (Aust.), dark minerals found with alluvial gold.
Black tin (Corn.), dressed tin ore.
Blanch, lead ore mixed with other minerals.
Blanched copper, copper alloyed with arsenic.
Blanket strake (Aust.), sloping tables or sluices lined with baize for catching gold.
Blick (Germ.), iridescence on gold and silver at end of cupelling.
Blind creek (Aust.), dry watercourse.
Blind level, (1) an incomplete level; (2) a drainage level.
Bloat, a hammer swelled at the eye.
Block claim (Aust.), a square mining claim.
Block tin, cast tin.
Blocking out (Aust.), washing gold gravel in sections.
Bloomary, a forge for making wrought iron.
Blossom, the decomposed outcrop of a vein or coal-bed.
Blower (N. Eng.), an outrush of gas.
Blue-billy, residue of copper pyrites after roasting with salt.
Blue elvan (Corn.), greenstone.
Blue-john (Derb.), fluorspar.
Blue lead (W. Amer.), a blue-stained stratum of gravel of great extent and richness.
Blue peach (Corn.), a slate-blue fine-grained schorl.
Blue stone, copper sulphate.
Bob (Corn.), triangular frame transmitting power from engine to pump-rods.
Boca (Span.), mine mouth.
Bocamina (Span.), mine mouth.
Bog iron ore, loose earthy brown hematite recently formed in swampy ground.
Boliche (Span.), concentrating bowl.

Bollos (Span.), triangular blocks of amalgam.
Bolsa (Span.), small bunch of ore.
Bonanza (Span.), body of rich ore.
Bone, slaty matter in coal seams.
Bonnet, the roof of a cage.
Bonney (Corn.), an isolated body of ore.
Bonze, undressed lead ore.
Booming, removing gravel by sudden outlets of pent-up water.
Borrasca (Span.), unprofitable ore.
Bort, amorphous dark diamond.
Bottoms, impure copper alloy below the matt in smelting.
Bounds (Corn.), a tract of tin ground.
Bout (Derb.), 24 dishes of lead ore.
Bowke (Staff.), small wooden box for hauling ironstone underground
Bowse (Derb.), lead ore as cut from the lode.
Box-bill, tool for recovering boring-rods.
Brace (Corn.), buildings at pit mouth.
Braize (Amer.) charcoal dust.
Brake-sieve, hand jigger.
Brances, iron pyrites in coal.
Branch, small vein shooting off from main lode.
Brasses, iron pyrites in coal.
Brat, a thin bed of coal mixed with pyrites or limestone.
Brattice, a lining or partition.
Brazil (N. Eng.), iron pyrites in coal.
Breeze, small coke.
Brettis (Derb.), a timber crib filled with slack.
Broaching bit, a tool for re-opening bore-hole which has partially closed by swelling of the walls.
Brob, a spike to prevent timber slipping.
Broil (Corn.), traces of a vein in loose matter.
Brooch (Corn.), mixed ores.
Brood (Corn.), heavy waste from tin and copper ores.
Brownspar, ferruginous dolomite.
Browse, imperfectly smelted ore mixed with cinder and clay.
Bryle (Corn.), traces of a vein in loose matter.
Bucking, breaking down ore with a very broad hammer ready for jigging.
Buddle, an inclined stationary or revolving platform, on which ores are dressed.
Buitron (Span.), a silver furnace.
Bulkhead, (1) a tight partition, or stopping; (2) the end of a flume carrying water for hydraulicing.
Bulldog, furnace lining.
Bully, a miners' hammer.
Bunch, a small rich ore body.
Bunding, a staging in a level for carrying débris.
Bunney, a nest of ore not lying in a regular vein.
Burden, earth overlying a bed of useful mineral.

Burr, solid rock.
Burrow, refuse heap.
Buscones (Span.), prospectors, fossickers, tribute workers.
Butt, coal surface exposed at right angles to the face.
Butty (Mid.), a contract miner.

Cabezuela (Span.), rich gold and silver concentrates.
Cal (Corn.), wolfram.
Cala (Span.), prospecting pit.
Caliche (Span.), felspar.
Callys (Corn.), stratified rocks traversed by lodes.
Canch, stone quarry.
Cancha (Span.), space for drying slimes.
Cand (Corn.), fluorspar.
Cank (Derb.), whinstone.
Caple (Corn.), hard rock lining tin lodes.
Carbona (Corn.), an irregular deposit of tin ore.
Case, a fissure admitting water into a mine.
Cata (Span.), a mine denounced but not worked.
Cauf (N. Eng.), a coal bucket or basket.
Caunter (Corn.), a vein crossing diagonally.
Cawk, baryta sulphate.
Cazeador (Span.), amalgamator.
Chats (N. Eng.), small pieces of stone with ore.
Chilian mill, a mortar mill.
Chimney, an ore shoot.
Choke-damp, carbonic acid gas.
Chuza (Span.), a washer.
Claggy (N. Eng.), when coal is tightly joined to the roof.
Claim, a portion of mining ground held under one grant.
Clean-up, collecting the product of a period of work with battery or sluice.
Cleat, (1) a joint in rock; (2) a wedge.
Clod, soft shale or slate roof to coal.
Coal-pipes (N. Eng.) very thin irregular coal beds.
Cob (Corn.), to break up ore for sorting.
Cobre, Cuban copper ores.
Cockle (Corn.), black tourmaline, often mistaken for tin.
Cod (N. Eng.), the bearing of an axle.
Cofer (Derb.), to caulk a shaft by ramming clay behind the lining.
Coffer, the iron box in which stamps work.
Coffin (Corn.), an old pit.
Coil drag, a tool for picking pebbles, &c., from drill holes.
Colas (Span.), brown sulphides.
Colorados (Span.), decomposed ores stained with iron.
Colours, particles of gold found in panning a sample.
Colrake, a shovel for stirring lead ores while washing.
Cope (Derb.), lead mining on contract.
Copela (Span.), dry amalgam.

Copelilla (Span.), zinc-bende.
Corbond, an irregular mass from a lode.
Corf, a mine wagon or tub.
Coro-coro (S. Amer.), grains of native copper mixed with pyrite, chalco-pyrite, mispickel, &c.
Corve, a mining wagon or tub.
Cost-book (Corn.), mining accounts.
Costean (Corn.), to prospect a lode by sinking pits on its supposed course.
Country, the formation traversed by a lode.
Cow, a self-acting brake.
Coyoting (W. Amer.), irregular mining by small pits.
Crab-hole (Aust.), water-worn holes in bed rock.
Cradle, a wooden trough for washing gold sands.
Cramp, a pillar left for support in a mine.
Cranch, part of a vein left by previous workers.
Creaze (Corn.), tin ore collected in the middle of the buddle.
Creep, movement of walls or floor of a mine.
Crib, a timber frame.
Cribble, a sieve.
Crop (Corn.), the richest portion of dressed tin ore.
Cross-course, a cross vein.
Cross-cut, a level driven across a vein.
Crosses and holes (Derb.), made in the ground by the discoverer of a lode to temporarily secure possession.
Crow-foot, a tool for drawing broken boring rods.
Culm (Eng.), anthracite; (N. Amer.), fine waste coal and dirt.
Curb, a timber frame.

Dam, a barrier for water or gases.
Damp, poisonous gas.
Dan (N. Eng.), a truck without wheels.
Dant (N. Eng.), soft inferior coal.
Dead, (1) unproductive; (2) unventilated.
Dead men's graves (Aust.), grave-like mounds in the basalt underlying auriferous gravels.
Dead riches (N. Amer.), lead carrying much bullion.
Dead roasting, roasting till all sulphur is driven off.
Deads, rubbish.
Dead work, unproductive work.
Dean (Corn.), the end of a level.
Desaguador (Span.) a water pipe or drain.
Desecho (Span.), floured mercury.
Desmontes (Span.), poor ores.
Despoblado (Span.), ore with much gangue.
Dessue (Corn.), to cut away the ground beside a thin vein so as to remove the latter whole.
Dialling, surveying.
Dillueing (Corn.), dressing tin slimes in a fine sieve.

Dippa (Corn.), a small catch-water pit.
Dish (Corn.), an ore measure; in lead mines a trough 28 in. long, 4 in. deep, and 6 in. broad; sometimes 1 gal., sometimes 14–16 pints.
Dizzue (Corn.), see Dessue.
Dolly, (1) a perforated board for breaking up clay in puddling; (2) a primitive quartz stamp.
Donk (N. Eng.), soft mineral found in cross veins.
Dradge (Corn.), inferior ore separated from the prill.
Dresser (Staff.), a large coal pick.
Drift, (1) a tunnel following the vein; (2) alluvial deposits.
Dropper, a branch leaving the vein on the footwall side.
Druggon (Staff.), a vessel for carrying fresh water into a mine.
Dumb'd, choked—of a sieve or grating.
Dump, a heap of ore or refuse.
Durn (Corn.), a timber frame.
Dürr (Germ.), barren ground.
Dzhu (Corn.), see Dessue.

Efydd (Wales), copper.
Elvan (Corn.), a belt of felspathic or porphyritic rock.
Estano (Span.), tin.

Fahlband (Germ.), a course impregnated with metallic sulphides.
Faiscador (Span.), a gold-washer.
False bottom, a bed of rock under alluvial which has other alluvial below it.
Famp (N. Eng.), thin beds of soft tough shale.
Fang (Derb.), an air course.
Fast (Corn.), bedrock.
Feigh (N. Eng.), ore refuse.
Ferro blanco (Span.), arsenopyrite.
Flang (Corn.), a double-pointed pick.
Flat wall (Corn.), footwall.
Float, detached fragments of a quartz reef.
Floran (Corn.), very fine tin.
Flouring, the breaking-up and contamination of mercury, rendering it useless for amalgamating.
Flucan (Corn.), clayey matter in a lode.
Fluke, a rod for cleaning out drill-holes.
Flume, a water conduit.
Fluthwerk (Germ.), river prospecting.
Fodder (N. Eng.), 21 cwt. of lead.
Foot (Corn.), 2 gal. or 60 lb. black tin.
Force piece, diagonal timbering to secure the ground.
Fork (Corn.), bottom of sump; (Derb.), prop for soft ground.
Fossicking, casual and unsystematic mining.
Fother (N. Eng.), $\frac{1}{8}$ chaldron.
Free milling, ores requiring no roasting or chemical treatment.

Gad, a wedge.
Gal (Corn.), hard gossan.
Gale, a grant of mining ground.
Galemador (Span.), a silver furnace.
Galiage, royalty.
Gangue, refuse associated with ore.
Ganister, furnace lining composed of fire clay and ground quartz.
Gatches (Corn.), final sludge from tin dressing.
Glist (Corn.), micaceous iron ore.
Goaf, worked-out ground, and the refuse with which it is filled.
Gob, see Goaf.
Gossan (Corn.), ferruginous quartz or calcspar filling a lode.
Goths (Staff.), sudden burstings of coal from the face owing to tension caused by unequal pressure.
Gouge (N. Amer.), soft clay lying between the ore body and sides of the lode.
Grass, surface.
Grassero (Span.), slag-heap.
Grena (Span.), undressed ore.
Grizzly (W. Amer.), a grating to throw out large stones from hydraulic gold sluices.
Groove (Derb.), a mine.
Growan (Corn.), granite.
Grundy, granulated pig iron.
Gunny (Corn.), worked-out ground.
Gubbin, ironstone.
Guija (Span.), quartz.
Gunnies (Corn.), 3 ft.
Gurt (Corn.), water runnel from dressing-floor.

Haiarn (Wales), iron.
Halvans (Corn.), inferior copper ore.
Hard-head, residue from tin refining; contains much iron and arsenic.
Hazle (N. Eng.), sandstone mixed with shale.
Hechado (Span.), dip.
Hilo (Span.), a thin metalliferous vein.
Hulk (Corn.), to pick out the soft portions of a lode.
Hungry, worthless looking.
Hushing, prospecting by laying ground bare by sudden discharges of pent-up water.
Hutch (Corn.), an ore-washing box.
Hydraulicing (W. Amer.), working auriferous gravel beds by hydraulic power.

Inch, Miners', see p. 23.
Irestone (Corn.), any hard tough stone.
Iron hat, decomposed ferruginous mineral capping a lode.
Itabirite (Braz.), micaceous iron ore.

Jacotinga (Braz.), ferruginous ores associated with gold.
Jales (Span.), tailings.
Jigging, separating heavy from light particles by agitation in water.
Judge (Derb. and N. Eng.), a measuring staff.

Kann (Corn.), fluorspar.
Kazen (Corn.), a sieve.
Keckle-meckle, poorest lead ore.
Kerned (Corn.), pyrites hardened by exposure.
Kevil (Derb.), a calcspar found in lead veins.
Kibble, a mining bucket.
Kieve, tossing-tub.
Killas (Corn.), clay slate.
Kirving (N. Eng.), the cutting made beneath the coal seam.

Lama (Span.), slimes.
Lappior (Corn.), an ore dresser.
Launder, water trough.
Lazyback (Staff.), a coal stack.
Leat, water-course.
Leavings (Corn.), halvans.
Limadura de plata (Span.), dry silver amalgam.
Linnets (Derb.), oxidised lead ores.
Lista (Span.), tail of impure mercury.
Long-tom, a gold-washing trough.
Loob (Corn.), sludge from tin dressing.

Macizo (Span.), unworked lode.
Magistral (Span.), roasted copper pyrites, copper sulphate, &c., used to reduce silver ores.
Makings (N. Eng.), small coal produced in kirving.
Manga (Span.), canvas bag for straining amalgam.
Maquilla (Span.), a custom mill.
Marmajas (Span.), concentrated sulphides.
Maza (Span.), stamp head.
Mear (Derb.), 32 yd. along the vein.
Miners' inch, see p. 23.
Mistress (N. Eng.), a miners' lamp.
Mock-lead (Corn.), zinc-blende.
Moil (Corn.), a wedge-pointed drill.
Mucks (Staff.), bad earthy coal.
Mundic, pyrites.

Negrillo (Span.), black sulphide of silver.
Nittings, refuse of good ore.
Noria (Span.), an endless chain of buckets.
Nuts, coal of a certain size.

Oro (Span.), gold.
Oroche (Span.), retorted bullion.
Overburden, soil overlying a bed of useful mineral.

Packing (Corn.), final dressing of tin or copper ore.
Pacos (Span.), ferruginous silver ores.
Panning, washing earth or crushed rock in a shallow dish (see p. 325).
Pasilla (Span.), dry silver amalgam.
Peach stone (Corn.), chlorite schist.
Pee (Derb.). a fragment of lead ore.
Pepenado (Span.), dressed ore.
Pitch (Corn.), portion of lode worked by tributers.
Pillion (Corn.), metal remaining in slag.
Piping, hydraulicing.
Placer, an alluvial mine.
Plata (Span.), silver.
Plata cornea amarillia (Span.), iodyrite.
Plata cornea blanca (Span.), cerargyrite.
Plata cornea verde (Span.), embolite.
Plata mixta (Span.), gold and silver alloy.
Plata negra (Span.), argentite.
Plata pasta (Span.), spongy silver bars after retorting.
Plata piña (Span.), silver after retorting.
Plata verde (Span.), bromyrite.
Plate (N. Eng.), scaly shale in limestone beds.
Plomb d'œuvre (Fr.), dressed galena.
Plomo (Span.), lead, galena.
Plush copper, chalcotrichite.
Plwm (Wales), lead.
Poch-erz (Germ.), ore requiring to be crushed and dressed.
Podar (Corn.), copper pyrites.
Polroz (Corn.), water-wheel pit.
Polvillos (Span.), rich ores.
Polvoulla (Span.), black silver.
Pot growan (Corn.), decomposed granite.
Prian (Corn.), soft white clay.
Prill (Corn.). the best ore after cobbing.
Pryan (Corn.), see Prian.
Pulp, crushed ore, wet or dry.

Quajado (Span.), dull lead ore.
Quetschwerk (Germ.), ore requiring to be crushed and dressed.
Quick, (1) productive; (2) mercury.
Quillato (Span.), carat.

Rabban (Corn.), yellow dry gossan.
Rack (Corn.), a stationary buddle.
Raffain (Corn.), poor ore.

Rag burning (Corn.), the first roasting of tin-witts.
Ragging (Corn.), rough cobbing.
Rake (Corn.), a vein: (Derb.), fissure vein crossing strata.
Ramble (N. Eng.), shale bed overlying coal.
Red rab (Corn.) red slaty rock.
Reliz (Span.), wall of lode.
Rick (N. Amer.), open heap in which coal is coked.
Riffle, a groove or check on the floor of a sluice to catch gold.
Rimrock, bed rock forming a boundary to gravel deposit.
Rosiclara (Span.), ruby silver ore.
Roughs (Corn.), second quality tin sands.

Scovan (Corn.), a tin lode showing no gossan at surface.
Scove (Corn.), purest tin ore.
Scrin (Derb.), a small vein.
Scrowl (Corn.), loose ore where a vein is crossed.
Seam (Corn.), a horse-load of ore.
Shadd (Corn.), rounded fragments of ore overlying a vein.
Shet (Staff.), fallen roof of coal mine.
Shoad (Corn.), see Shadd.
Shoading (Corn.), prospecting.
Sickening, see Flouring.
Siddle, inclination.
Skimpings (Corn.), the poorest ore skimmed off the jigger.
Skip, a box for raising ore.
Skit (Corn.), a pump.
Slack, small coal.
Sleck (Derb.), mud in a mine.
Sleeping-table (Corn.), a buddle.
Slickensides, polished surfaces of vein walls.
Slimes, most finely crushed ore.
Sludge, see Slimes.
Sluice, a long channel in rock or of timber, with checks to catch gold.
Slurry (N. Wales), half smelted ore.
Smeddum, lead ore dust.
Smut (Staff.), soft bad coal.
Sollar (Corn.), platform, landing.
Spall, to break ore for dressing.
Speiss (Germ.), impure arsenides produced in copper and lead smelting.
Spiegeleisen (Germ.), manganiferous white cast iron.
Spills (Corn.), a temporary lagging driven ahead on levels in loose ground.
Squat (Corn.), tin ore mixed with spar.
Standage, pump reservoir.
Stannary, tin works.
Stope, to excavate mineral in a series of steps.
Stowce, (1) windlass; (2) landmarks.

Strake, an inclined table or trough for separating metal from refuse.
Studdles, timber props.
Stull, platform to carry miners or waste.
Stup, powdered coke or coal mixed with clay.
Sturt, a tribute bargain profitable to the miner.
Stythe (N. Eng.), choke-damp.
Sweeping-table, a stationary buddle.
Swither (N. Amer.), a crevice branching from a main lead lode.

Tailings, the refuse flowing from the tail or lowest end of the apparatus.
Teem, to pour or tip.
Tepetate (Span.), rubbish.
Thill (N. Eng.), floor of coal mine.
Thurl (Staff.), to cut through from one working into another.
Ticketing (Corn.), purchasing ore by tender on tickets.
Tierras (Span.), earth impregnated with mercury ore.
Tin-witts (Corn.), product of first dressing of tin ores, containing also wolfram and sulphides.
Tossing, shaking powdered ore in water to effect separation of heavy and light particles.
Trapiche (Span.), a primitive grinding mill.
Treloobing (Corn.), stirring tin slimes in water.
Tributers, miners paid by results.
Turbary, a peat bog.
Tut-work, work paid for by the piece, not by results.
Tye, a strake.

Van, to dress or concentrate ore by hand or machine.
Vend (N. Eng.), total sales of coal from a mine.
Vestry (N. Eng.), refuse.
Vinney, copper ore with green efflorescence.
Vugh (Corn.), a cavity.

Wale (N. Eng.), hand-dressing coal.
Wash dirt, auriferous gravel.
Weeldon, old ironstone workings.
Whim, a winding drum.
Whip, a winding pulley.
Whits, see Tin-witts.
Wild lead, zinc blende.
Winze, interior shaft connecting levels.
Wythern (Wales), lode.

Yellow ore (Corn.), chalco-pyrite.

LIST OF USEFUL BOOKS.

André, G. G., Coal Mining, 72*s.*

Beringer, C. & J. J., Text-book of Assaying, for use of those connected with mines, 10*s.* 6*d.*

Bloxam, C. L., and Huntington, A. K., Metals, their Properties and Treatment, 5*s.*

Bowie, A. J., Hydraulic Mining, 21*s.*

Brough, B. H., Mine Surveying, 7*s.* 6*d.*

Brown, W. L., Manual of Assaying Gold, Silver, Copper, and Lead Ores, 12*s.* 6*d.*

Charleton, A. G., Tin Mining, Dressing, and Smelting; with notes on arsenic, bismuth, and wolfram, 12*s.* 6*d.*

Crew, B. J., Practical Treatise on Petroleum, 21*s.*

Dana, J. D., Manual of Mineralogy and Petrography, 10*s.* 6*d.*

Davies, D. C., Metalliferous Minerals and Mining, 12*s.* 6*d.*

—— —— Earthy and other Minerals and Mining, 12*s.* 6*d.*

—— —— Slate and Slate Quarrying, 3*s.* 6*d.*

Dron, R. W., Text-book of Mining Formulæ, 1*s.* 9*d.*

Fairley, W., Colliery Manager's Calculator, 4*s.*

Greenwell, G. C., Mining Engineering, 15*s.*

Gresley, W. S., Glossary of Terms used in Coal Mining, 5*s.*

Hiorns, A. H., Practical Metallurgy and Assaying, 6*s.*

Hunt, R., British Mining, 42*s.*

Kirkpatrick, T. S. G., Hydraulic Gold Miner's Manual, 6*s.*

Kunhardt, W. B., Ore Dressing in Europe, 6*s.*

Lock, C. G. W., Mining and Ore-dressing Machinery, 52*s.* 6*d.*

—— —— Practical Gold Mining, 42*s.*

M'Dermott, W., and Duffield, P. W., Losses in Gold Amalgamation, 5*s.*

Merivale, J. H., Notes and Formulæ for Mining Students, 2*s.* 6*d.*

Osborn, H. S., Practical Manual of Minerals, Mines, and Mining, 21*s.*

Pamely, C., Colliery Manager's Handbook, 25*s.*

Penning, W. H., Engineering Geology, 3*s.* 6*d.*

—— —— Field Geology, 7*s.* 6*d.*

Percy, C. M., Mechanical Engineering of Collieries, 40*s.*

Phillips, J. A., Ore Deposits, 25*s.*

Randall, P. M., Quartz Operator's Handbook, 10*s.* 6*d.*

Sawyer, A. R., Accidents in Mines; their causes and means of diminishing their frequency, 21*s.*

Smyth, W. W., Coal and Coal Mining, 4*s.*

Stone, T. W., Simple Hydraulic Formulæ, 6*s.*

Van Wagenen, T. F., Manual of Hydraulic Mining, 5*s.*

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
0°	1.00000	0.00000	2.00000	0.00000	3.00000	0.00000	4.00000	0.00000	5.00000	0.00000	60'
2'	1.00000	0.00058	2.00000	0.00116	3.00000	0.00174	4.00000	0.00232	5.00000	0.00290	58
4	0.99999	0.00116	1.99998	0.00232	2.99997	0.00348	3.99996	0.00464	4.99995	0.00580	56
6	0.99999	0.00174	1.99998	0.00348	2.99997	0.00522	3.99996	0.00696	4.99995	0.00870	54
8	0.99999	0.00232	1.99998	0.00464	2.99997	0.00696	3.99996	0.00928	4.99995	0.01160	52
10	0.99999	0.00290	1.99998	0.00580	2.99997	0.00870	3.99996	0.01160	4.99995	0.01450	50
12	0.99999	0.00349	1.99998	0.00698	2.99997	0.01047	3.99996	0.01396	4.99995	0.01745	48
14	0.99999	0.00407	1.99998	0.00814	2.99997	0.01221	3.99996	0.01628	4.99995	0.02035	46
16	0.99998	0.00465	1.99996	0.00930	2.99994	0.01395	3.99992	0.01860	4.99990	0.02325	44
18	0.99998	0.00523	1.99996	0.01046	2.99994	0.01569	3.99992	0.02092	4.99990	0.02615	42
20	0.99998	0.00581	1.99996	0.01162	2.99994	0.01743	3.99992	0.02324	4.99990	0.02905	40
22	0.99997	0.00639	1.99994	0.01278	2.99991	0.01917	3.99988	0.02556	4.99985	0.03195	38
24	0.99997	0.00698	1.99994	0.01396	2.99991	0.02094	3.99988	0.02792	4.99985	0.03490	36
26	0.99997	0.00756	1.99994	0.01512	2.99991	0.02268	3.99988	0.03024	4.99985	0.03780	34
28	0.99996	0.00814	1.99992	0.01628	2.99988	0.02442	3.99984	0.03256	4.99980	0.04070	32
30	0.99996	0.00872	1.99992	0.01744	2.99988	0.02616	3.99984	0.03488	4.99980	0.04360	30
32	0.99995	0.00930	1.99990	0.01860	2.99985	0.02790	3.99980	0.03720	4.99975	0.04650	28
34	0.99995	0.00989	1.99990	0.01978	2.99985	0.02967	3.99980	0.03956	4.99975	0.04945	26
36	0.99994	0.01047	1.99988	0.02094	2.99982	0.03141	3.99976	0.04188	4.99970	0.05235	24
38	0.99993	0.01105	1.99986	0.02210	2.99979	0.03315	3.99972	0.04420	4.99965	0.05525	22
40	0.99993	0.01163	1.99986	0.02326	2.99979	0.03489	3.99972	0.04652	4.99965	0.05815	20
42	0.99992	0.01221	1.99984	0.02442	2.99976	0.03663	3.99968	0.04884	4.99960	0.06105	18
44	0.99991	0.01279	1.99982	0.02558	2.99973	0.03837	3.99964	0.05116	4.99955	0.06395	16
46	0.99991	0.01338	1.99982	0.02676	2.99973	0.04014	3.99964	0.05352	4.99955	0.06690	14
48	0.99990	0.01396	1.99980	0.02792	2.99970	0.04188	3.99960	0.05584	4.99950	0.06980	12
50	0.99989	0.01454	1.99978	0.02908	2.99967	0.04362	3.99956	0.05816	4.99945	0.07270	10
52	0.99988	0.01512	1.99976	0.03024	2.99964	0.04536	3.99952	0.06048	4.99940	0.07560	8
54	0.99987	0.01570	1.99974	0.03140	2.99961	0.04710	3.99948	0.06280	4.99935	0.07850	6
56	0.99986	0.01628	1.99972	0.03256	2.99958	0.04884	3.99944	0.06512	4.99930	0.08141	4
58	0.99985	0.01687	1.99970	0.03374	2.99955	0.05061	3.99940	0.06748	4.99925	0.08435	2
60	0.99984	0.01745	1.99968	0.03490	2.99952	0.05235	3.99936	0.06980	4.99920	0.08725	89°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
1°	0.99984	0.01745	1.99968	0.03490	2.99952	0.05236	3.99936	0.06980	4.99920	0.08725	60'
2	0.99983	0.01803	1.99966	0.03606	2.99949	0.05409	3.99932	0.07212	4.99915	0.09015	58
4	0.99982	0.01861	1.99964	0.03722	2.99946	0.05583	3.99928	0.07444	4.99910	0.09305	56
6	0.99981	0.01919	1.99962	0.03838	2.99943	0.05757	3.99924	0.07676	4.99905	0.09595	54
8	0.99980	0.01977	1.99960	0.03954	2.99940	0.05931	3.99920	0.07908	4.99900	0.09885	52
10	0.99979	0.02036	1.99958	0.04072	2.99937	0.06108	3.99916	0.08144	4.99895	0.10180	50
12	0.99978	0.02094	1.99956	0.04188	2.99934	0.06282	3.99912	0.08376	4.99890	0.10470	48
14	0.99976	0.02152	1.99952	0.04304	2.99928	0.06456	3.99904	0.08608	4.99880	0.10760	46
16	0.99975	0.02210	1.99950	0.04420	2.99925	0.06630	3.99900	0.08840	4.99875	0.11050	44
18	0.99974	0.02268	1.99948	0.04536	2.99922	0.06804	3.99896	0.09072	4.99870	0.11340	42
20	0.99972	0.02326	1.99944	0.04652	2.99916	0.06975	3.99888	0.09304	4.99860	0.11630	40
22	0.99971	0.02385	1.99942	0.04770	2.99913	0.07155	3.99884	0.09540	4.99855	0.11925	38
24	0.99970	0.02443	1.99940	0.04886	2.99910	0.07329	3.99880	0.09772	4.99850	0.12215	36
26	0.99968	0.02501	1.99936	0.05002	2.99904	0.07503	3.99872	0.10004	4.99840	0.12505	34
28	0.99967	0.02559	1.99934	0.05118	2.99901	0.07677	3.99868	0.10236	4.99835	0.12795	32
30	0.99966	0.02617	1.99932	0.05234	2.99898	0.07851	3.99864	0.10468	4.99830	0.13055	30
32	0.99964	0.02675	1.99928	0.05350	2.99892	0.08025	3.99856	0.10700	4.99820	0.13375	28
34	0.99962	0.02734	1.99924	0.05469	2.99886	0.08202	3.99848	0.10936	4.99810	0.13670	26
36	0.99961	0.02792	1.99922	0.05584	2.99883	0.08376	3.99844	0.11168	4.99805	0.13960	24
38	0.99959	0.02850	1.99915	0.05700	2.99877	0.08550	3.99836	0.11400	4.99795	0.14250	22
40	0.99951	0.02908	1.99914	0.05816	2.99871	0.08724	3.99828	0.11632	4.99785	0.14540	20
42	0.99955	0.02966	1.99910	0.05932	2.99865	0.08898	3.99820	0.11864	4.99775	0.14830	18
44	0.99954	0.03024	1.99908	0.06049	2.99862	0.09072	3.99816	0.12096	4.99770	0.15120	16
46	0.99952	0.03082	1.99904	0.06164	2.99856	0.09246	3.99808	0.12328	4.99760	0.15410	14
48	0.99950	0.03141	1.99900	0.06282	2.99850	0.09423	3.99800	0.12564	4.99750	0.15705	12
50	0.99948	0.03199	1.99896	0.06398	2.99844	0.09597	3.99792	0.12796	4.99740	0.15995	10
52	0.99946	0.03257	1.99892	0.06514	2.99838	0.09771	3.99784	0.13028	4.99730	0.16285	8
54	0.99945	0.03315	1.99890	0.06630	2.99835	0.09945	3.99780	0.13260	4.99725	0.16575	6
56	0.99943	0.03373	1.99886	0.06746	2.99829	0.10119	3.99772	0.13492	4.99715	0.16865	4
58	0.99941	0.03431	1.99882	0.06862	2.99823	0.10293	3.99764	0.13724	4.99705	0.17155	2
60	0.99939	0.03489	1.99878	0.06978	2.99817	0.10467	3.99756	0.13956	4.99695	0.17445	88°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
2°	0.99939	0.03489	1.99878	0.06978	2.99817	0.10467	3.99756	0.13956	4.99695	0.17445	60'
2	0.99937	0.03548	1.99874	0.07096	2.99811	0.10644	3.99748	0.14192	4.99685	0.17740	58
4	0.99934	0.03606	1.99868	0.07212	2.99802	0.10818	3.99736	0.14424	4.99670	0.18030	56
6	0.99932	0.03664	1.99864	0.07328	2.99796	0.10992	3.99728	0.14656	4.99660	0.18320	54
8	0.99930	0.03722	1.99860	0.07444	2.99790	0.11166	3.99720	0.14888	4.99650	0.18610	52
10	0.99928	0.03780	1.99856	0.07560	2.99784	0.11340	3.99712	0.15120	4.99640	0.18900	50
12	0.99926	0.03838	1.99852	0.07676	2.99778	0.11514	3.99704	0.15352	4.99630	0.19190	48
14	0.99924	0.03897	1.99848	0.07792	2.99772	0.11688	3.99696	0.15584	4.99620	0.19480	46
16	0.99921	0.03955	1.99842	0.07910	2.99763	0.11865	3.99684	0.15820	4.99605	0.19775	44
18	0.99919	0.04013	1.99838	0.08026	2.99757	0.12039	3.99676	0.16052	4.99595	0.20065	42
20	0.99917	0.04071	1.99834	0.08142	2.99751	0.12213	3.99668	0.16284	4.99585	0.20355	40
22	0.99914	0.04129	1.99828	0.08258	2.99742	0.12387	3.99656	0.16516	4.99570	0.20645	38
24	0.99912	0.04187	1.99824	0.08374	2.99736	0.12561	3.99648	0.16748	4.99560	0.20935	36
26	0.99909	0.04245	1.99818	0.08490	2.99727	0.12735	3.99636	0.16980	4.99545	0.21225	34
28	0.99907	0.04303	1.99814	0.08606	2.99721	0.12909	3.99628	0.17212	4.99535	0.21515	32
30	0.99904	0.04361	1.99808	0.08722	2.99712	0.13083	3.99616	0.17444	4.99520	0.21805	30
32	0.99902	0.04420	1.99804	0.08840	2.99706	0.13260	3.99608	0.17680	4.99510	0.22100	28
34	0.99898	0.04478	1.99796	0.08956	2.99694	0.13434	3.99592	0.17912	4.99490	0.22390	26
36	0.99897	0.04536	1.99794	0.09072	2.99691	0.13608	3.99588	0.18144	4.99485	0.22680	24
38	0.99894	0.04594	1.99788	0.09188	2.99682	0.13782	3.99576	0.18376	4.99470	0.22970	22
40	0.99891	0.04652	1.99782	0.09304	2.99673	0.13956	3.99564	0.18608	4.99455	0.23260	20
42	0.99888	0.04710	1.99776	0.09420	2.99664	0.14130	3.99552	0.18840	4.99440	0.23550	18
44	0.99886	0.04768	1.99772	0.09536	2.99658	0.14304	3.99544	0.19072	4.99430	0.23840	16
46	0.99883	0.04826	1.99766	0.09652	2.99649	0.14478	3.99532	0.19304	4.99415	0.24130	14
48	0.99880	0.04884	1.99760	0.09768	2.99640	0.14652	3.99520	0.19536	4.99400	0.24420	12
50	0.99877	0.04943	1.99754	0.09886	2.99631	0.14829	3.99508	0.19772	4.99385	0.24715	10
52	0.99874	0.05001	1.99748	0.10002	2.99622	0.15003	3.99496	0.20004	4.99370	0.25005	8
54	0.99871	0.05059	1.99742	0.10118	2.99613	0.15177	3.99484	0.20236	4.99355	0.25295	6
56	0.99868	0.05117	1.99736	0.10234	2.99604	0.15351	3.99472	0.20468	4.99340	0.25585	4
58	0.99865	0.05175	1.99730	0.10350	2.99595	0.15525	3.99460	0.20700	4.99325	0.25875	2
60	0.99862	0.05233	1.99724	0.10466	2.99586	0.15699	3.99448	0.20932	4.99310	0.26165	87°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
3°	0.99862	0.05234	1.99724	0.10468	2.99586	0.15702	3.99448	0.20936	4.99310	0.261[illegible]9	60′
2	0.99859	0.05291	1.99718	0.10582	2.99577	0.15873	3.99436	0.21164	4.99295	0.26455	58
4	0.99856	0.05349	1.99712	0.10698	2.99568	0.16047	3.99424	0.21396	4.99280	0.26745	56
6	0.99853	0.05407	1.99706	0.10814	2.99559	0.16221	3.99412	0.21628	4.99265	0.27035	54
8	0.99850	0.05465	1.99700	0.10930	2.99550	0.16395	3.99400	0.21860	4.99250	0.27325	52
10	0.99847	0.05524	1.99694	0.11048	2.99541	0.16572	3.99388	0.22096	4.99235	0.27620	50
12	0.99844	0.05582	1.99688	0.11164	2.99532	0.16746	3.99376	0.22328	4.99220	0.27910	48
14	0.99840	0.05640	1.99680	0.11280	2.99520	0.16920	3.99360	0.22560	4.99200	0.28200	46
16	0.99837	0.05698	1.99674	0.11396	2.99511	0.17094	3.99348	0.22792	4.99185	0.28490	44
18	0.99334	0.05756	1.99668	0.11512	2.99502	0.17268	3.99336	0.23024	4.99170	0.28780	42
20	0.99830	0.05814	1.99660	0.11628	2.99490	0.17442	3.99320	0.23256	4.99150	0.29070	40
22	0.99827	0.05872	1.99654	0.11744	2.99481	0.17616	3.99308	0.23488	4.99135	0.29360	38
24	0.99823	0.05930	1.99646	0.11860	2.99469	0.17790	3.99392	0.23720	4.99115	0.29650	36
26	0.99820	0.05988	1.99640	0.11976	2.99460	0.17964	3.99280	0.23952	4.99100	0.29940	34
28	0.99817	0.06046	1.99634	0.12092	2.99451	0.18138	3.99268	0.24184	4.99085	0.30230	32
30	0.99813	0.06104	1.99626	0.12208	2.99439	0.18312	3.99252	0.24416	4.99065	0.30520	30
32	0.99809	0.06162	1.99618	0.12324	2.99427	0.18486	3.99236	0.24648	4.99045	0.30810	28
34	0.99806	0.06220	1.99612	0.12440	2.99418	0.18660	3.99224	0.24880	4.99030	0.31100	26
36	0.99802	0.06279	1.99604	0.12558	2.99406	0.18837	3.99208	0.25116	4.99010	0.31395	24
38	0.99799	0.06337	1.99598	0.12674	2.99397	0.19011	3.99196	0.25348	4.98995	0.31685	22
40	0.99795	0.06395	1.99590	0.12790	2.99385	0.19185	3.99180	0.25580	4.98975	0.31975	20
42	0.99791	0.06453	1.99582	0.12906	2.99373	0.19359	3.99164	0.25812	4.98955	0.32265	18
44	0.99787	0.06511	1.99574	0.13022	2.99361	0.19533	3.99148	0.26044	4.98935	0.32555	16
46	0.99784	0.06569	1.99568	0.13138	2.99356	0.19707	3.99136	0.26276	4.98920	0.32845	14
48	0.99780	0.06627	1.99560	0.13254	2.99340	0.19881	3.99120	0.26508	4.98900	0.33135	12
50	0.99776	0.06685	1.99552	0.13370	2.99328	0.20055	3.99104	0.26740	4.98880	0.33425	10
52	0.99772	0.06743	1.99544	0.13486	2.99316	0.20229	3.99088	0.26972	4.98860	0.33715	8
54	0.99768	0.06801	1.99536	0.13602	2.99304	0.20403	3.99072	0.27204	4.98840	0.34005	6
56	0.99764	0.06859	1.99528	0.13718	2.99292	0.20577	3.99056	0.27436	4.98820	0.34295	4
58	0.99760	0.06917	1.99520	0.13834	2.99280	0.20751	3.99040	0.27668	4.98800	0.34585	2
60	0.99756	0.06975	1.99512	0.13950	2.99268	0.20925	3.99024	0.27900	4.98780	0.34875	86°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
4°	0.99756	0.06976	1.99512	0.13952	2.99268	0.20928	3.99024	0.27904	4.98780	0.34880	60'
2'	0.99752	0.07033	1.99504	0.14066	2.99256	0.21099	3.99008	0.28132	4.98760	0.35165	58
4	0.99748	0.07091	1.99496	0.14182	2.99244	0.21273	3.98992	0.28364	4.98740	0.35155	56
6	0.99744	0.07149	1.99488	0.14298	2.99232	0.21447	3.98976	0.28596	4.98720	0.35745	54
8	0.99739	0.07207	1.99478	0.14414	2.99217	0.21621	3.98956	0.28828	4.98695	0.36035	52
10	0.99735	0.07265	1.99470	0.14530	2.99205	0.21795	3.98940	0.29060	4.98675	0.36325	50
12	0.99731	0.07323	1.99462	0.14646	2.99193	0.21969	3.98924	0.29292	4.98655	0.36615	48
14	0.99727	0.07381	1.99454	0.14762	2.99171	0.22143	3.98908	0.29524	4.98635	0.36905	46
16	0.99722	0.07439	1.99444	0.14878	2.99166	0.22317	3.98888	0.29756	4.98610	0.37195	44
18	0.99718	0.07497	1.99436	0.14994	2.99154	0.22491	3.98872	0.29988	4.98590	0.37485	42
20	0.99714	0.07555	1.99428	0.15110	2.99142	0.22665	3.98856	0.30220	4.98570	0.37775	40
22	0.99709	0.07613	1.99418	0.15226	2.99127	0.22839	3.98836	0.30452	4.98545	0.38065	38
24	0.99705	0.07671	1.99410	0.15342	2.99115	0.23013	3.98820	0.30684	4.98525	0.38355	36
26	0.99700	0.07729	1.99400	0.15458	2.99100	0.23187	3.98800	0.30916	4.98500	0.38645	34
28	0.99696	0.07787	1.99392	0.15574	2.99088	0.23361	3.98784	0.31148	4.98480	0.38935	32
30	0.99691	0.07845	1.99382	0.15690	2.99073	0.23535	3.98764	0.31380	4.98455	0.69225	30
32	0.99687	0.07903	1.99374	0.15806	2.99061	0.23709	3.98748	0.31612	4.98435	0.39515	28
34	0.99682	0.07961	1.99364	0.15922	2.99046	0.23883	3.98728	0.31844	4.98410	0.39805	26
36	0.99677	0.08019	1.99354	0.16038	2.99031	0.24057	3.98708	0.32076	4.98385	0.40095	24
38	0.99673	0.08077	1.99346	0.16154	2.99019	0.24231	3.98692	0.32308	4.98365	0.40385	22
40	0.99668	0.08135	1.99336	0.16270	2.99004	0.24405	3.98672	0.32540	4.98340	0.40675	20
42	0.99663	0.08193	1.99326	0.16380	2.98989	0.24579	3.98652	0.32772	4.98315	0.40965	18
44	0.99658	0.08251	1.99316	0.16502	2.98974	0.24753	3.98632	0.33004	4.98290	0.41255	16
46	0.99654	0.08309	1.99308	0.16618	2.98962	0.24927	3.98616	0.33236	4.98270	0.41545	14
48	0.99649	0.08367	1.99298	0.16734	2.98947	0.25101	3.98596	0.33468	4.98245	0.41835	12
50	0.99644	0.08425	1.99288	0.16850	2.98932	0.25275	3.98576	0.33700	4.98220	0.42125	10
52	0.99639	0.08483	1.99278	0.16966	2.98917	0.25449	3.98556	0.33932	4.98195	0.42415	8
54	0.99634	0.08541	1.99268	0.17082	2.98902	0.25623	3.98536	0.34164	4.98170	0.42705	6
56	0.99629	0.08599	1.99258	0.17198	2.98887	0.25797	3.98516	0.34396	4.98145	0.42995	4
58	0.99624	0.08657	1.99248	0.17314	2.98872	0.25971	3.98496	0.34628	4.98120	0.43285	2
60	0.99619	0.08715	1.99238	0.17430	2.98857	0.26145	3.98476	0.34860	4.98095	0.43575	85°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
5°	0.996194	0.087155	1.992388	0.174310	2.988582	0.261465	3.984776	0.348620	4.980970	0.435775	60'
2'	0.996143	0.087735	1.992286	0.175470	2.988429	0.263205	3.984572	0.350940	4.980715	0.438675	58
4	0.996092	0.088314	1.992184	0.176628	2.988276	0.264942	3.984368	0.353256	4.980460	0.441570	56
6	0.996041	0.088894	1.992082	0.177788	2.988123	0.266682	3.984164	0.355576	4.980205	0.444470	54
8	0.995989	0.089473	1.991978	0.178946	2.987967	0.268419	3.983956	0.357892	4.979945	0.447365	52
10	0.995937	0.090053	1.991874	0.180106	2.987811	0.270159	3.983748	0.360212	4.979685	0.450265	50
12	0.995884	0.090632	1.991768	0.181264	2.987652	0.271896	3.983536	0.362528	4.979420	0.453160	48
14	0.995831	0.091211	1.991662	0.182422	2.987493	0.273633	3.983324	0.364844	4.979155	0.456055	46
16	0.995778	0.091791	1.991556	0.183582	2.987334	0.275373	3.983112	0.367164	4.978890	0.458955	44
18	0.995724	0.092370	1.991448	0.184740	2.987172	0.277110	3.982896	0.369480	4.978620	0.461850	42
20	0.995670	0.092949	1.991340	0.185898	2.987010	0.278847	3.982680	0.371796	4.978350	0.464745	40
22	0.995616	0.093529	1.991232	0.187058	2.986848	0.280587	3.982464	0.374116	4.978080	0.467645	38
24	0.995562	0.094108	1.991124	0.188216	2.986686	0.282324	3.982248	0.376432	4.977810	0.470540	36
26	0.995507	0.094687	1.991014	0.189374	2.986521	0.284061	3.982028	0.378748	4.977535	0.473435	34
28	0.995451	0.095266	1.990902	0.190532	2.986353	0.285798	3.981804	0.381064	4.977255	0.476330	32
30	0.995396	0.095845	1.990792	0.191690	2.986188	0.287535	3.981584	0.383380	4.976980	0.479225	30
32	0.995340	0.096424	1.990680	0.192848	2.986020	0.289272	3.981360	0.385696	4.976700	0.482120	28
34	0.995284	0.097003	1.990568	0.194006	2.985852	0.291009	3.981136	0.388012	4.976420	0.485015	26
36	0.995227	0.097582	1.990454	0.195164	2.985681	0.292746	3.980908	0.390328	4.976135	0.487910	24
38	0.995170	0.098161	1.990340	0.196322	2.985510	0.294483	3.980680	0.392644	4.975850	0.490805	22
40	0.995113	0.098740	1.990226	0.197480	2.985339	0.296220	3.980452	0.394960	4.975565	0.493700	20
42	0.995055	0.099319	1.990110	0.198638	2.985165	0.297957	3.980220	0.397276	4.975275	0.496595	18
44	0.994997	0.099898	1.989994	0.199796	2.984991	0.299694	3.979988	0.399592	4.974985	0.499490	16
46	0.994939	0.100477	1.989878	0.200954	2.984817	0.301431	3.979756	0.401908	4.974695	0.502385	14
48	0.994880	0.101056	1.989760	0.202112	2.984640	0.303168	3.979520	0.404224	4.974400	0.505280	12
50	0.994821	0.101635	1.989642	0.203270	2.984463	0.304905	3.979284	0.406540	4.974105	0.508175	10
52	0.994762	0.102213	1.989524	0.204426	2.984286	0.306639	3.979048	0.408852	4.973810	0.511065	8
54	0.994702	0.102792	1.989404	0.205584	2.984106	0.308376	3.978808	0.411168	4.973510	0.513960	6
56	0.994642	0.103371	1.989284	0.206742	2.983926	0.310113	3.978568	0.413484	4.973210	0.516855	4
58	0.994582	0.103949	1.989164	0.207898	2.983746	0.311847	3.978328	0.415796	4.972910	0.519745	2
60	0.994521	0.104528	1.989042	0.209056	2.983563	0.313584	3.978084	0.418112	4.972605	0.522640	84°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
6°	0.994521	0.104528	1.989042	0.209056	2.983563	0.313584	3.978084	0.418112	4.972605	0.522640	60'
2	0.994460	0.105107	1.988920	0.210214	2.983380	0.315321	3.977840	0.420428	4.972300	0.525535	58
4	0.994399	0.105685	1.988798	0.211370	2.983197	0.317055	3.977596	0.422740	4.971995	0.528425	56
6	0.994337	0.106264	1.988674	0.212528	2.983011	0.318792	3.977348	0.425056	4.971685	0.531320	54
8	0.994276	0.106842	1.988552	0.213684	2.982828	0.320526	3.977104	0.427368	4.971380	0.534210	52
10	0.994213	0.107421	1.988426	0.214842	2.982639	0.322263	3.976852	0.429684	4.971065	0.537105	50
12	0.994151	0.107999	1.988302	0.215998	2.982453	0.323997	3.976604	0.431996	4.970755	0.539995	48
14	0.994088	0.108577	1.988176	0.217154	2.982264	0.325731	3.976352	0.434308	4.970440	0.542885	46
16	0.994024	0.109156	1.988048	0.218312	2.982072	0.327468	3.976096	0.436624	4.970120	0.545780	44
18	0.993961	0.109734	1.987922	0.219468	2.981883	0.329202	3.975844	0.438936	4.969805	0.548670	42
20	0.993896	0.110312	1.987792	0.220624	2.981688	0.330936	3.975584	0.441248	4.969480	0.551560	40
22	0.993832	0.110890	1.987664	0.221780	2.981496	0.332670	3.975328	0.443560	4.969160	0.554450	38
24	0.993767	0.111468	1.987534	0.222936	2.981301	0.334404	3.975068	0.445872	4.968835	0.557340	36
26	0.993702	0.112047	1.987404	0.224094	2.981106	0.336141	3.974808	0.448188	4.968510	0.560235	34
28	0.993637	0.112625	1.987274	0.225250	2.980911	0.337875	3.974548	0.450500	4.968185	0.563125	32
30	0.993571	0.113203	1.987142	0.226406	2.980713	0.339609	3.974284	0.452812	4.967855	0.566015	30
32	0.993505	0.113781	1.987010	0.227562	2.980515	0.341343	3.974020	0.455124	4.967525	0.568905	28
34	0.993439	0.114359	1.986878	0.228718	2.980317	0.343077	3.973756	0.457436	4.967195	0.571795	26
36	0.993372	0.114937	1.986744	0.229874	2.980116	0.344811	3.973488	0.459748	4.966860	0.574685	24
38	0.993305	0.115515	1.986610	0.231030	2.979915	0.346545	3.973220	0.462060	4.966525	0.577575	22
40	0.993238	0.116092	1.986476	0.232184	2.979714	0.348276	3.972952	0.464368	4.966190	0.580460	20
42	0.993170	0.116670	1.986340	0.233340	2.979510	0.350010	3.972680	0.466680	4.965850	0.583350	18
44	0.993102	0.117248	1.986204	0.234496	2.979306	0.351744	3.972408	0.468992	4.965510	0.586240	16
46	0.993034	0.117826	1.986068	0.235652	2.979102	0.353478	3.972136	0.471304	4.965170	0.589130	14
48	0.992965	0.118404	1.985930	0.236808	2.978895	0.355212	3.971860	0.473616	4.964825	0.592020	12
50	0.992896	0.118981	1.985792	0.237962	2.978688	0.356943	3.971584	0.475924	4.964480	0.594905	10
52	0.992827	0.119559	1.985654	0.239118	2.978481	0.358677	3.971308	0.478236	4.964135	0.597795	8
54	0.992757	0.120136	1.985514	0.240272	2.978271	0.360408	3.971028	0.480544	4.963785	0.600680	6
56	0.992687	0.120714	1.985374	0.241428	2.978061	0.362142	3.970748	0.482856	4.963435	0.603570	4
58	0.992616	0.121291	1.985232	0.242582	2.977848	0.363873	3.970464	0.485164	4.963080	0.606455	2
60	0.992546	0.121869	1.985092	0.243738	2.977638	0.365607	3.970184	0.487476	4.962730	0.609345	83°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude or North or South Distance	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
7°	0.992546	0.121869	1.985092	0.243738	2.977638	0.365607	3.970184	0.487476	4.962730	0.609345	60′
2	0.992475	0.122446	1.984950	0.244892	2.977426	0.367338	3.969900	0.489784	4.962375	0.612230	58
4	0.992403	0.123024	1.984806	0.246048	2.977209	0.369072	3.969612	0.492096	4.962015	0.615120	56
6	0.992331	0.123601	1.984662	0.247202	2.976993	0.370803	3.969324	0.494404	4.961655	0.618005	54
8	0.992259	0.124178	1.984518	0.248356	2.976777	0.372534	3.969036	0.496712	4.961295	0.620890	52
10	0.992187	0.124756	1.984374	0.249512	2.976561	0.374268	3.968748	0.499024	4.960935	0.623780	50
12	0.992114	0.125333	1.984228	0.250666	2.976342	0.375999	3.968456	0.501332	4.960570	0.626665	48
14	0.992041	0.125910	1.984082	0.251820	2.976123	0.377730	3.968164	0.503640	4.960205	0.629550	46
16	0.991968	0.126487	1.983936	0.252974	2.975905	0.379461	3.967872	0.505948	4.959840	0.632435	44
18	0.991894	0.127064	1.983788	0.254128	2.975682	0.381192	3.967576	0.508256	4.959 70	0.635320	42
20	0.991820	0.127641	1.983640	0.255282	2.975460	0.382923	3.967280	0.510564	4.959100	0.638205	40
22	0.991745	0.128218	1.983490	0.256436	2.975235	0.384654	3.966980	0.512872	4.958725	0.641090	38
24	0.991671	0.128795	1.983342	0.257590	2.975013	0.386385	3.966684	0.515180	4.958355	0.643975	36
26	0.991596	0.129372	1.983192	0.258744	2.974788	0.388116	3.966384	0.517488	4.957980	0.646860	34
28	0.991520	0.129949	1.983040	0.259898	2.974560	0.389847	3.966080	0.519796	4.957600	0.649745	32
30	0.991444	0.130526	1.982888	0.261052	2.974332	0.391578	3.965776	0.522104	4.957220	0.652630	30
32	0.991368	0.131103	1.982736	0.262206	2.974104	0.393309	3.965472	0.524412	4.956840	0.655515	28
34	0.991292	0.131679	1.982584	0.263358	2.973876	0.395037	3.965160	0.526716	4.956460	0.658395	26
36	0.991215	0.132256	1.982430	0.264512	2.973645	0.396768	3.964860	0.529024	4.956075	0.661280	24
38	0.991138	0.132833	1.982276	0.265666	2.973414	0.398499	3.964552	0.531332	4.955690	0.664165	22
40	0.991061	0.133409	1.982122	0.266818	2.973183	0.400227	3.964242	0.533636	4.955305	0.667045	20
42	0.990983	0.133986	1.981966	0.267972	2.972949	0.401958	3.963932	0.535944	4.954915	0.669930	18
44	0.990905	0.134562	1.981810	0.269124	2.972715	0.403686	3.963620	0.538248	4.954525	0.672810	16
46	0.990826	0.135139	1.981652	0.270278	2.972478	0.405417	3.963304	0.540556	4.954130	0.675695	14
48	0.990747	0.135715	1.981494	0.271436	2.972241	0.407145	3.962988	0.542860	4.953735	0.678575	12
50	0.990668	0.136291	1.981336	0.272582	2.972004	0.408873	3.962672	0.545164	4.953340	0.681455	10
52	0.990589	0.136868	1.981178	0.273736	2.971767	0.410604	3.962356	0.547472	4.952945	0.684340	8
54	0.990509	0.137444	1.981018	0.274888	2.971527	0.412332	3.962036	0.549776	4.952545	0.687220	6
56	0.990429	0.138020	1.980858	0.276040	2.971287	0.414060	3.961716	0.552080	4.952145	0.690100	4
58	0.990348	0.138597	1.980696	0.277194	2.971044	0.415791	3.961392	0.554388	4.951740	0.692985	2
60	0.990268	0.139173	1.980536	0.278346	2.970804	0.417519	3.961072	0.556692	4.951340	0.695865	82°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude. or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
8°	0.990268	0.139173	1.980536	0.278346	2.970804	0.417519	3.961072	0.556692	4.951340	0.695865	60′
2′	0.990186	0.139749	1.980372	0.279498	2.970558	0.419247	3.960744	0.558996	4.950930	0.698745	58
4	0.990105	0.140325	1.980210	0.280650	2.970315	0.420975	3.960420	0.561300	4.950525	0.701625	56
6	0.990023	0.140901	1.980046	0.281802	2.970069	0.422703	3.960092	0.563604	4.950115	0.704505	54
8	0.989941	0.141477	1.979882	0.282954	2.969823	0.424431	3.959764	0.565908	4.949705	0.707385	52
10	0.989859	0.142053	1.979718	0.284106	2.969577	0.426159	3.959436	0.568212	4.949295	0.710265	50
12	0.989776	0.142628	1.979552	0.285256	2.969328	0.427884	3.959104	0.570512	4.948880	0.713140	48
14	0.989693	0.143204	1.979386	0.286408	2.969079	0.429612	3.958772	0.572816	4.948465	0.716020	46
16	0.989609	0.143780	1.979218	0.287560	2.968827	0.431340	3.958436	0.575120	4.948045	0.718900	44
18	0.989525	0.144356	1.979050	0.288712	2.968575	0.433068	3.958100	0.577424	4.947625	0.721780	42
20	0.989441	0.144931	1.978882	0.289862	2.968323	0.434793	3.957764	0.579724	4.947205	0.724655	40
22	0.989357	0.145507	1.978714	0.291014	2.968071	0.436521	3.957428	0.582028	4.946785	0.727535	38
24	0.989272	0.146083	1.978544	0.292166	2.967816	0.438249	3.957088	0.584332	4.946360	0.730415	36
26	0.989187	0.146658	1.978374	0.293316	2.967561	0.439974	3.956748	0.586632	4.945935	0.733290	34
28	0.989101	0.147234	1.978202	0.294468	2.967303	0.441702	3.956404	0.588936	4.945505	0.736170	32
30	0.989015	0.147809	1.978030	0.295618	2.967045	0.443427	3.956060	0.591236	4.945075	0.739045	30
32	0.988929	0.148384	1.977858	0.296768	2.966787	0.445152	3.955716	0.593536	4.944645	0.741920	28
34	0.988843	0.148960	1.977686	0.297920	2.966529	0.446880	3.955372	0.595840	4.944215	0.744800	26
36	0.988756	0.149535	1.977512	0.299070	2.966268	0.448605	3.955024	0.598140	4.943780	0.747675	24
38	0.988669	0.150110	1.977338	0.300220	2.966007	0.450330	3.954676	0.600440	4.943345	0.750550	22
40	0.988581	0.150685	1.977162	0.301370	2.965743	0.452055	3.954324	0.602740	4.942905	0.753425	20
42	0.988493	0.151260	1.976986	0.302520	2.965479	0.453780	3.953972	0.605040	4.942465	0.756300	18
44	0.988405	0.151835	1.976810	0.303670	2.965215	0.455505	3.953620	0.607340	4.942025	0.759175	16
46	0.988317	0.152410	1.976634	0.304820	2.964951	0.457230	3.953268	0.609640	4.941585	0.762050	14
48	0.988228	0.152985	1.976456	0.305970	2.964684	0.458955	3.952912	0.611940	4.941140	0.764925	12
50	0.988139	0.153560	1.976278	0.307120	2.964417	0.460680	3.952556	0.614240	4.940695	0.767800	10
52	0.988049	0.154135	1.976098	0.308270	2.964147	0.462405	3.952196	0.616540	4.940245	0.770675	8
54	0.987959	0.154710	1.975918	0.309420	2.963877	0.464130	3.951836	0.618840	4.939795	0.773550	6
56	0.987869	0.155285	1.975738	0.310570	2.963607	0.465855	3.951476	0.621140	4.939345	0.776425	4
58	0.987779	0.155859	1.975558	0.311718	2.963337	0.467577	3.951116	0.623436	4.938895	0.779295	2
60	0.987688	0.156434	1.975376	0.312868	2.963064	0.469302	3.950752	0.625736	4.938440	0.782170	81°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latit·de, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
9°	0.987688	0.156434	1.975376	0.312868	2.963064	0.469302	3.950752	0.625736	4.938440	0.782170	60'
2	0.987597	0.157009	1.975194	0.314018	2.962791	0.471027	3.950388	0.628036	4.937985	0.785045	58
4	0.987505	0.157583	1.975010	0.315166	2.962515	0.472749	3.950020	0.630332	4.937525	0.787915	56
6	0.987413	0.158158	1.974826	0.316316	2.962239	0.474474	3.949652	0.632632	4.937065	0.790790	54
8	0.987321	0.158732	1.974642	0.317464	2.961963	0.476196	3.949284	0.634928	4.936605	0.793660	52
10	0.987229	0.159306	1.974458	0.318612	2.961687	0.477918	3.948916	0.637224	4.936145	0.796530	50
12	0.987136	0.159881	1.974272	0.319762	2.961408	0.479643	3.948544	0.639524	4.935680	0.799405	48
14	0.987043	0.160455	1.974086	0.320910	2.961129	0.481365	3.948172	0.641820	4.935215	0.802275	46
16	0.986949	0.161029	1.973898	0.322058	2.960847	0.483087	3.947796	0.644116	4.934745	0.805145	44
18	0.986855	0.161603	1.973710	0.323206	2.960565	0.484809	3.947420	0.646412	4.934275	0.808015	42
20	0.986761	0.162177	1.973522	0.324354	2.960283	0.486531	3.947044	0.648708	4.933805	0.810885	40
22	0.986667	0.162752	1.973334	0.325504	2.960001	0.488256	3.946668	0.651008	4.933335	0.813760	38
24	0.986572	0.163326	1.973144	0.326652	2.959716	0.489978	3.946288	0.653304	4.932860	0.816630	36
26	0.986477	0.163899	1.972954	0.327798	2.959431	0.491697	3.945908	0.655596	4.932385	0.819495	34
28	0.986381	0.164473	1.972762	0.328946	2.959143	0.493419	3.945524	0.657892	4.931905	0.822365	32
30	0.986285	0.165047	1.972570	0.330094	2.958855	0.495141	3.945140	0.660188	4.931425	0.825325	30
32	0.986189	0.165621	1.972378	0.331242	2.958567	0.496863	3.944756	0.662484	4.930945	0.828105	28
34	0.986092	0.166195	1.972184	0.332390	2.958276	0.498585	3.944368	0.664780	4.930460	0.830975	26
36	0.985996	0.166768	1.971992	0.333536	2.957988	0.500304	3.943984	0.667072	4.929980	0.833840	24
38	0.985898	0.167342	1.971796	0.334684	2.957694	0.502026	3.943592	0.669368	4.929490	0.836710	22
40	0.985801	0.167915	1.971602	0.335830	2.957403	0.503745	3.943204	0.671660	4.929005	0.839575	20
42	0.985703	0.168489	1.971406	0.336978	2.957109	0.505467	3.942812	0.673956	4.928515	0.842445	18
44	0.985605	0.169062	1.971210	0.338124	2.956815	0.507186	3.942420	0.676248	4.928025	0.845310	16
46	0.985506	0.169636	1.971012	0.339272	2.956518	0.508908	3.942024	0.678544	4.927530	0.848180	14
48	0.985407	0.170209	1.970814	0.340418	2.956221	0.510627	3.941628	0.680836	4.927035	0.851045	12
50	0.985308	0.170782	1.970616	0.341564	2.955924	0.512346	3.941232	0.683128	4.926540	0.853910	10
52	0.985209	0.171356	1.970418	0.342712	2.955627	0.514068	3.940836	0.685424	4.926045	0.856780	8
54	0.985109	0.171929	1.970218	0.343858	2.955327	0.515787	3.940436	0.687716	4.925545	0.859645	6
56	0.985009	0.172502	1.970018	0.345004	2.955027	0.517506	3.940036	0.690008	4.925045	0.862510	4
58	0.984908	0.173075	1.969816	0.346150	2.954724	0.519225	3.939632	0.692300	4.924540	0.865378	2
60	0.984807	0.173648	1.969614	0.347296	2.954421	0.520944	3.939228	0.694592	4.924035	0.868240	80°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
10°	0.984807	0.173648	1.969614	0.347296	2.954421	0.520944	3.939228	0.694592	4.924035	0.868240	60′
2′	0.984706	0.174221	1.969412	0.348442	2.954118	0,522663	3.938824	0.696884	4.923530	0.871105	58
4	0.984605	0.174793	1.969210	0.349586	2.953815	0.524379	3.938420	0.699172	4.923025	0.873965	56
6	0.984503	0.175366	1.969006	0.350732	2.953509	0.526098	3.938012	0.701464	4.922515	0.876830	54
8	0.984401	0.175939	1.968802	0.351878	2.953203	0.527817	3.937604	0.703756	4.922005	0.879695	52
10	0.984298	0.176512	1.968596	0.353024	2.952894	0.529536	3.937192	0.706048	4.921490	0.882560	50
12	0.984195	0.177084	1.968390	0.354168	2.952585	0.531252	3.936780	0.708336	4.920975	0.885420	48
14	0.984092	0.177657	1.968184	0.355314	2.952276	0.532971	3.936368	0.710628	4.920460	0.888285	46
16	0.983988	0.178229	1.967976	0.356458	2.951964	0.534687	3.935952	0.712916	4.919940	0.891145	44
18	0.983885	0.178802	1.967770	0.357604	2.951655	0.536406	3.935540	0.715208	4.919425	0.894010	42
20	0.983780	0.179374	1.967560	0.358748	2.951340	0.538122	3.935120	0.717496	4.918900	0.896870	40
22	0.983676	0.179946	1.967352	0.359892	2.951028	0.539838	3.934704	0.719784	4.918380	0.899730	38
24	0.983571	0.180519	1.967142	0.361038	2.950713	0.541557	3.934284	0.722076	4.917855	0.902595	36
26	0.983466	0.181091	1.966932	0.362182	2.950398	0.543273	3.933864	0.724364	4.917330	0.905455	34
28	0.983360	0.181663	1.966720	0.363326	2.950080	0.544989	3.933440	0.726652	4.916800	0.908315	32
30	0.983254	0.182235	1.966508	0.364470	2.949762	0.546705	3.933016	0.728940	4.916270	0.911175	30
32	0.983148	0.182807	1.966296	0.365614	2.949444	0.548421	3.932592	0.731228	4.915740	0.914035	28
34	0.983042	0.183379	1.966084	0.366758	2.949126	0.550137	3.932168	0.733516	4.915210	0.916895	26
36	0.982935	0.183951	1.965870	0.367902	2.948805	0.551853	3.931740	0.735804	4.914675	0.919755	24
38	0.982828	0.184523	1.965656	0.369046	2.948484	0.553569	3.931312	0.738092	4.914140	0.922615	22
40	0.982720	0.185094	1.965440	0.370188	2.948160	0.555282	3.930880	0.740376	4.913600	0.925470	20
42	0.982612	0.185666	1.965224	0.371332	2.947836	0.556998	3.930448	0.742664	4.913060	0.928330	18
44	0.982504	0.186238	1.965008	0.372476	2.947512	0.558714	3.930016	0.744952	4.912520	0.931190	16
46	0.982396	0.186809	1.964792	0.373618	2.947188	0.560427	3.929584	0.747236	4.911980	0.934045	14
48	0.982287	0.187381	1.964574	0.374762	2.946861	0.562143	3.929148	0.749524	4.911435	0.936905	12
50	0.982178	0.187952	1.964356	0.375904	2.946534	0.563856	3.928712	0.751808	4.910890	0.939760	10
52	0.982068	0.188524	1.964136	0.377048	2.946204	0.565572	3.928272	0.754096	4.910340	0.942620	8
54	0.981958	0.189095	1.963916	0.378190	2.945874	0.567285	3.927832	0.756380	4.909790	0.945475	6
56	0.981848	0.189666	1.963696	0.379332	2.945544	0.568998	3.927392	0.758664	4.909240	0.948330	4
58	0.981738	0.190237	1.963476	0.380474	2.945214	0.570711	3.926952	0.760948	4.908690	0.951185	2
60	0.981627	0.190809	1.963254	0.381618	2.944881	0.572427	3.926508	0.763236	4.908135	0.954045	79°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000. Distance from Planes of Meridian, or East or West Distance.	
11°	0.981627	0.190809	1.963254	0.381618	2.944881	0.572427	3.926508	0.763236	4.908135	0.954045	60′
2	0.981516	0.191380	1.963032	0.382760	2.944548	0.574140	3.926064	0.765520	4.907580	0.956900	58
4	0.981404	0.191951	1.962808	0.383902	2.944212	0.575853	3.925616	0.767804	4.907020	0.959755	56
6	0.981292	0.192522	1.962584	0.385044	2.943876	0.577566	3.925168	0.770088	4.906460	0.962610	54
8	0.981180	0.193092	1.962360	0.386184	2.943540	0.579276	3.924720	0.772368	4.905900	0.965460	52
10	0.981068	0.193663	1.962136	0.387326	2.943204	0.580989	3.924272	0.774652	4.905340	0.968315	50
12	0.980955	0.194234	1.961910	0.388468	2.942865	0.582702	3.923820	0.776936	4.904775	0.971170	48
14	0.980842	0.194805	1.961684	0.389610	2.942526	0.584415	3.923368	0.779220	4.904210	0.974025	46
16	0.980728	0.195375	1.961456	0.390750	2.942184	0.586125	3.922912	0.781500	4.903640	0.976875	44
18	0.980614	0.195946	1.961228	0.391892	2.941842	0.587838	3.922456	0.783784	4.903070	0.979730	42
20	0.980500	0.196516	1.961000	0.393032	2.941500	0.589548	3.922000	0.786064	4.902500	0.982580	40
22	0.980386	0.197087	1.960772	0.394174	2.941158	0.591261	3.921544	0.788348	4.901930	0.985435	38
24	0.980271	0.197657	1.960542	0.395314	2.940813	0.592971	3.921084	0.790628	4.901355	0.988285	36
26	0.980156	0.198227	1.960312	0.396454	2.940468	0.594681	3.920624	0.792908	4.900780	0.991135	34
28	0.980040	0.198797	1.960080	0.397594	2.940120	0.596391	3.920160	0.795188	4.900200	0.993985	32
30	0.979924	0.199367	1.959848	0.398734	2.939772	0.598101	3.919696	0.797468	4.899620	0.996835	30
32	0.979808	0.199938	1.959616	0.399876	2.939424	0.599814	3.919232	0.799752	4.899040	0.999690	28
34	0.979692	0.200508	1.959384	0.401016	2.939076	0.601524	3.918768	0.802032	4.898460	1.002540	26
36	0.979575	0.201077	1.959150	0.402154	2.938725	0.603231	3.918300	0.804308	4.897875	1.005385	24
38	0.979458	0.201647	1.958916	0.403294	2.938374	0.604941	3.917832	0.806588	4.897290	1.008235	22
40	0.979340	0.202217	1.958680	0.404434	2.938020	0.606651	3.917360	0.808868	4.896700	1.011085	20
42	0.979222	0.202787	1.958444	0.405574	2.937666	0.608361	3.916886	0.811148	4.896110	1.013935	18
44	0.979104	0.203356	1.958208	0.406712	2.937312	0.610068	3.916416	0.813424	4.895520	1.016780	16
46	0.978986	0.203926	1.957972	0.407852	2.936958	0.611778	3.915944	0.815704	4.894930	1.019630	14
48	0.978867	0.204496	1.957734	0.408992	2.936601	0.613488	3.915468	0.817984	4.894335	1.022480	12
50	0.978748	0.205065	1.957496	0.410130	2.936244	0.615195	3.914992	0.820260	4.893740	1.025325	10
52	0.978628	0.205634	1.957256	0.411268	2.935884	0.616902	3.914512	0.822536	4.893140	1.028170	8
54	0.978509	0.206204	1.957018	0.412408	2.935527	0.618612	3.914036	0.824816	4.892545	1.031020	6
56	0.978388	0.206773	1.956776	0.413546	2.935164	0.620319	3.913552	0.827092	4.891940	1.033865	4
58	0.978268	0.207342	1.956536	0.414684	2.934804	0.622026	3.913072	0.829368	4.891340	1.036710	2
60	0.978147	0.207911	1.956294	0.415822	2.934441	0.623733	3.912588	0.831644	4.890735	1.039555	78°
	Distance from Planes of Meridian, or East or West Distance. Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.	Distance from Planes of Latitude, or North or South Distance. Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.	Distance from Planes of Meridian, or East or West Distance. Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.	Distance from Planes of Latitude, or North or South Distance. Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.	Distance from Planes of Meridian, or East or West Distance. Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.	Distance from Planes of Latitude, or North or South Distance. Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.	Distance from Planes of Meridian, or East or West Distance. Measured Distance, or Hypothenuse 4, 40, 400, 4000, 40,000, or 400,000.	Distance from Planes of Latitude, or North or South Distance. Measured Distance, or Hypothenuse 4, 40, 400, 4000, 40,000, or 400,000.	Distance from Planes of Meridian, or East or West Distance. Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.	Distance from Planes of Latitude, or North or South Distance. Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.	Degrees and Minutes.

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
12°	0.978147	0.207911	1.956294	0.415822	2.934441	0.623733	3.912588	0.831644	4.890735	1.039555	60'
2'	0.978026	0.208480	1.956052	0.416960	2.934078	0.625440	3.912104	0.833920	4.890130	1.042400	58
4	0.977905	0.209049	1.955810	0.418098	2.933715	0.627147	3.911620	0.836196	4.889525	1.045245	56
6	0.977783	0.209618	1.955566	0.419236	2.933349	0.628854	3.911132	0.838472	4.888915	1.048090	54
8	0.977661	0.210187	1.955322	0.420374	2.932983	0.630561	3.910644	0.840748	4.888305	1.050935	52
10	0.977538	0.210756	1.955076	0.421512	2.932614	0.632268	3.910152	0.843024	4.887690	1.053780	50
12	0.977415	0.211324	1.954830	0.422648	2.932245	0.633972	3.909660	0.845296	4.887075	1.056620	48
14	0.977292	0.211893	1.954584	0.423786	2.931876	0.635679	3.909168	0.847572	4.886460	1.059465	46
16	0.977169	0.212461	1.954338	0.424922	2.931507	0.637383	3.908676	0.849844	4.885845	1.062305	44
18	0.977045	0.213030	1.954090	0.426060	2.931135	0.639090	3.908180	0.852120	4.885225	1.065150	42
20	0.976921	0.213598	1.953842	0.427196	2.930763	0.640794	3.907684	0.854392	4.884605	1.067990	40
22	0.976797	0.214167	1.953594	0.428334	2.930391	0.642501	3.907188	0.856668	4.883985	1.070835	38
24	0.976672	0.214735	1.953344	0.429470	2.930016	0.644205	3.906688	0.858940	4.883360	1.073675	36
26	0.976547	0.215303	1.953094	0.430606	2.929641	0.645909	3.906188	0.861212	4.882735	1.076515	34
28	0.976421	0.215871	1.952842	0.431742	2.929263	0.647613	3.905684	0.863484	4.882105	1.079355	32
30	0.976296	0.216439	1.952592	0.432878	2.928888	0.649317	3.905184	0.865756	4.881480	1.082195	30
32	0.976169	0.217007	1.952338	0.434014	2.928507	0.651021	3.904676	0.868028	4.880845	1.085035	28
34	0.976043	0.217575	1.952086	0.435150	2.928129	0.652725	3.904172	0.870300	4.880215	1.087875	26
36	0.975916	0.218143	1.951832	0.436286	2.927748	0.654429	3.903664	0.872572	4.879580	1.090715	24
38	0.975789	0.218711	1.951578	0.437422	2.927367	0.656133	3.903156	0.874844	4.878945	1.093555	22
40	0.975662	0.219278	1.951324	0.438556	2.926986	0.657834	3.902648	0.877112	4.878310	1.096390	20
42	0.975534	0.219846	1.951068	0.439692	2.926602	0.659538	3.902136	0.879384	4.877670	1.099230	18
44	0.975406	0.220413	1.950812	0.440826	2.926218	0.661239	3.901624	0.881652	4.877030	1.102065	16
46	0.975278	0.220981	1.950556	0.441962	2.925834	0.662943	3.901112	0.883924	4.876390	1.104905	14
48	0.975149	0.221548	1.950298	0.443096	2.925447	0.664644	3.900596	0.886192	4.875745	1.107740	12
50	0.975020	0.222115	1.950040	0.444230	2.925060	0.666345	3.900080	0.888460	4.875100	1.110575	10
52	0.974890	0.222683	1.949780	0.445366	2.924670	0.668049	3.899560	0.890732	4.874450	1.113415	8
54	0.974761	0.223250	1.949522	0.446500	2.924283	0.669750	3.899044	0.893000	4.873805	1.116250	6
56	0.974631	0.223817	1.949262	0.447634	2.923893	0.671451	3.898524	0.895268	4.873155	1.119085	4
58	0.974500	0.224384	1.949000	0.448768	2.923500	0.673152	3.898000	0.897536	4.872500	1.121920	2
60	0.974370	0.224951	1.948740	0.449902	2.923110	0.674853	3.897480	0.899804	4.871850	1.124755	77°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
13°	0.974370	0.224951	1.948740	0.449902	2.923110	0.674853	3.897480	0.899804	4.871850	1.124755	60′
2′	0.974239	0.225517	1.948478	0.451034	2.922717	0.676551	3.896956	0.902068	4.871195	1.127585	58
4	0.974107	0.226084	1.948214	0.452168	2.922321	0.678252	3.896428	0.904336	4.870535	1.130420	56
6	0.973976	0.226651	1.947952	0.453302	2.921928	0.679953	3.895904	0.906604	4.869880	1.133255	54
8	0.973843	0.227217	1.947686	0.454434	2.921529	0.681651	3.895372	0.908863	4.869215	1.136085	52
10	0.973711	0.227784	1.947422	0.455568	2.921133	0.683352	3.894844	0.911136	4.868555	1.138920	50
12	0.973578	0.228350	1.947156	0.456700	2.920734	0.685050	3.894312	0.913400	4.867890	1.141750	48
14	0.973445	0.228917	1.946890	0.457834	2.920335	0.686751	3.893780	0.915668	4.867225	1.144585	46
16	0.973312	0.229483	1.946624	0.458966	2.919936	0.688449	3.893248	0.917932	4.866560	1.147415	44
18	0.973178	0.230049	1.946356	0.460098	2.919534	0.690147	3.892712	0.920196	4.865890	1.150245	42
20	0.973044	0.230615	1.946088	0.461230	2.919132	0.691845	3.892176	0.922460	4.865220	1.153075	40
22	0.972910	0.231181	1.945820	0.462362	2.918730	0.693543	3.891640	0.924724	4.864550	1.155905	38
24	0.972775	0.231747	1.945550	0.463494	2.918325	0.695241	3.891100	0.926988	4.863875	1.158735	36
26	0.972640	0.232313	1.945280	0.464626	2.917920	0.696939	3.890560	0.929252	4.863200	1.161565	34
28	0.972505	0.232879	1.945010	0.465758	2.917515	0.698637	3.890020	0.931516	4.862525	1.164395	32
30	0.972369	0.233445	1.944738	0.466890	2.917107	0.700335	3.889476	0.933780	4.861845	1.167225	30
32	0.972233	0.234011	1.944466	0.468022	2.916699	0.702033	3.888932	0.936044	4.861165	1.170055	28
34	0.972097	0.234576	1.944194	0.469152	2.916291	0.703728	3.888388	0.938304	4.860485	1.172880	26
36	0.971961	0.235142	1.943922	0.470284	2.915883	0.705426	3.887844	0.940568	4.859805	1.175710	24
38	0.971824	0.235707	1.943648	0.471414	2.915472	0.707121	3.887296	0.942828	4.859120	1.178535	22
40	0.971686	0.236272	1.943372	0.472544	2.915058	0.708816	3.886744	0.945088	4.858430	1.181360	20
42	0.971549	0.236839	1.943098	0.473676	2.914647	0.710514	3.886196	0.947352	4.857745	1.184190	18
44	0.971411	0.237403	1.942822	0.474806	2.914233	0.712209	3.885644	0.949612	4.857055	1.187015	16
46	0.971272	0.237968	1.942544	0.475936	2.913816	0.713904	3.885088	0.951872	4.656360	1.189840	14
48	0.971134	0.238533	1.942268	0.477066	2.913402	0.715599	3.884536	0.954132	4.855670	1.192665	12
50	0.970995	0.239098	1.941990	0.478196	2.912985	0.717294	3.883980	0.956392	4.854975	1.195490	10
52	0.970856	0.239663	1.941712	0.479326	2.912568	0.718989	3.883424	0.958652	4.854280	1.198315	8
54	0.970716	0.240228	1.941432	0.480456	2.912148	0.720684	3.882864	0.960912	4.853580	1.201140	6
56	0.970576	0.240792	1.941152	0.481584	2.911728	0.722376	3.882304	0.963168	4.852880	1.203960	4
58	0.970436	0.241357	1.940872	0.483714	2.911308	0.724071	3.881744	0.967428	4.852180	1.206785	2
60	0.970295	0.241921	1.940590	0.483842	2.910885	0.725763	3.881180	0.967684	4.851475	1.209605	76°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
14°	0.970295	0.241921	1.940590	0.483842	2.910885	0.725763	3.881180	0.967684	4.851475	1.209605	60'
2'	0.970154	0.242486	1.940308	0.484972	2.910462	0.727458	3.880616	0.969944	4.850770	1.212430	58
4	0.970013	0.243050	1.940026	0.486100	2.910039	0.729150	3.880042	0.972200	4.850065	1.215250	56
6	0.969872	0.243615	1.939744	0.487230	2.909616	0.730845	3.879488	0.974460	4.849360	1.218075	54
8	0.969730	0.244179	1.939460	0.488358	2.909190	0.732537	3.878920	0.976716	4.848650	1.220895	52
10	0.969587	0.244743	1.939174	0.489486	2.908761	0.734229	3.878348	0.978972	4.847935	1.223715	50
12	0.969445	0.245307	1.938890	0.490614	2.908335	0.735921	3.877780	0.981228	4.847225	1.226535	48
14	0.969302	0.245871	1.938604	0.491742	2.907906	0.737613	3.877208	0.983484	4.846510	1.229355	46
16	0.969159	0.246435	1.938318	0.492870	2.907477	0.739305	3.876636	0.985740	4.845795	1.232175	44
18	0.969015	0.246999	1.938030	0.493998	2.907045	0.740997	3.876060	0.987996	4.845075	1.234995	42
20	0.968871	0.247562	1.937742	0.495124	2.906613	0.742656	3.875484	0.990248	4.844355	1.237810	40
22	0.968727	0.248126	1.937454	0.496252	2.906181	0.744378	3.874909	0.992504	4.843635	1.240630	38
24	0.968583	0.248689	1.937166	0.497378	2.905749	0.746067	3.874332	0.994756	4.842915	1.243445	36
26	0.968438	0.249253	1.936876	0.498506	2.905314	0.747759	3.873752	0.997012	4.842190	1.246265	34
28	0.968293	0.249816	1.936586	0.499632	2.904879	0.749448	3.873172	0.999264	4.841465	1.249080	32
30	0.968147	0.250380	1.936294	0.500760	2.904441	0.751140	3.872588	1.001520	4.840735	1.251900	30
32	0.968001	0.250943	1.936002	0.501886	2.904003	0.752829	3.872004	1.003772	4.840005	1.254715	28
34	0.967855	0.251506	1.935710	0.503012	2.903565	0.754518	3.871420	1.006024	4.839275	1.257530	26
36	0.967709	0.252069	1.935418	0.504138	2.903127	0.756207	3.870836	1.008276	4.838545	1.260345	24
38	0.967562	0.252632	1.935124	0.505264	2.902686	0.757896	3.870248	1.010528	4.837810	1.263160	22
40	0.967415	0.253195	1.934830	0.506390	2.902245	0.759585	3.869660	1.012780	4.837075	1.265975	20
42	0.967267	0.253757	1.934534	0.507514	2.901801	0.761271	3.869068	1.015028	4.836335	1.268785	18
44	0.967120	0.254320	1.934240	0.508640	2.901360	0.762960	3.868480	1.017280	4.835600	1.271600	16
46	0.966971	0.254883	1.933942	0.509766	2.900913	0.764649	3.867884	1.019532	4.834855	1.274415	14
48	0.966823	0.255445	1.933646	0.510890	2.900469	0.766335	3.867292	1.021780	4.834115	1.277225	12
50	0.966674	0.256008	1.933348	0.512016	2.900022	0.768024	3.866696	1.024032	4.833370	1.280040	10
52	0.966525	0.256570	1.933050	0.513140	2.899575	0.769710	3.866100	1.026280	4.832625	1.282850	8
54	0.966376	0.257132	1.932752	0.514264	2.899123	0.771396	3.865504	1.028528	4.831880	1.285660	6
56	0.966226	0.257695	1.932452	0.515390	2.898678	0.773085	3.864904	1.030780	4.831130	1.288475	4
58	0.966076	0.258257	1.932152	0.516514	2.898228	0.774771	3.864304	1.033028	4.830380	1.291285	2
60	0.965925	0.258819	1.931850	0.517638	2.897775	0.776457	3.863700	1.035276	4.829625	1.294095	75°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
15°	0.965925	0.258819	1.931850	0.517638	2.897775	0.776457	3.863700	1.035276	4.829625	1.294095	60′
2′	0.965775	0.259381	1.931550	0.518762	2.897325	0.778143	3.863100	1.037524	4.828875	1.296905	58
4	0.965624	0.259942	1.931248	0.519884	2.896872	0.779826	3.862496	1.039768	4.828120	1.299710	56
6	0.965472	0.260504	1.930944	0.521008	2.896416	0.781512	3.861888	1.042016	4.827360	1.302520	54
8	0.965320	0.261066	1.930640	0.522132	2.895960	0.783198	3.861280	1.044264	4.826600	1.305330	52
10	0.965168	0.261627	1.930336	0.523254	2.895504	0.784881	3.860672	1.046508	4.825840	1.308135	50
12	0.965016	0.262189	1.930032	0.524378	2.895048	0.786567	3.860064	1.048756	4.825080	1.310945	48
14	0.964863	0.262750	1.929726	0.525500	2.894589	0.788250	3.859452	1.051000	4.824315	1.313750	46
16	0.964710	0.263311	1.929420	0.526622	2.894130	0.789933	3.858840	1.053244	4.823550	1.316555	44
18	0.964557	0.263873	1.929114	0.527746	2.893671	0.791619	3.858228	1.055492	4.822785	1.319365	42
20	0.964403	0.264434	1.928806	0.528868	2.893209	0.793302	3.857612	1.057736	4.822015	1.322170	40
22	0.964249	0.264995	1.928498	0.529990	2.892747	0.794985	3.856996	1.059980	4.821245	1.324975	38
24	0.964095	0.265556	1.928190	0.531112	2.892285	0.796668	3.856380	1.062224	4.820475	1.327780	36
26	0.963940	0.266117	1.927880	0.532234	2.891820	0.798351	3.855760	1.064468	4.819700	1.330585	34
28	0.963785	0.266677	1.927570	0.533354	2.891355	0.800031	3.855140	1.066708	4.818925	1.333385	32
30	0.963630	0.267238	1.927260	0.534476	2.890890	0.802714	3.854520	1.068952	4.818150	1.336190	30
32	0.963474	0.267798	1.926948	0.535596	2.890422	0.803394	3.853896	1.071192	4.817370	1.338990	28
34	0.963318	0.268359	1.926636	0.536718	2.889954	0.805077	3.853272	1.073436	4.816590	1.341795	26
36	0.963162	0.268919	1.926324	0.537838	2.889486	0.806757	3.852648	1.075676	4.815810	1.344595	24
38	0.963006	0.269480	1.926012	0.538960	2.889018	0.808440	3.852024	1.077920	4.815030	1.347400	22
40	0.962849	0.270040	1.925693	0.540080	2.888547	0.810120	3.851396	1.080160	4.814245	1.350200	20
42	0.962691	0.270600	1.925382	0.541200	2.888073	0.811800	3.850764	1.082400	4.813455	1.353000	18
44	0.962534	0.271160	1.925068	0.542320	2.887602	0.813480	3.850136	1.084640	4.812670	1.355800	16
46	0.962376	0.271720	1.924752	0.543440	2.887128	0.815160	3.849504	1.086880	4.811880	1.358600	14
48	0.962218	0.272280	1.924436	0.544560	2.886654	0.816840	3.848872	1.089120	4.811090	1.361400	12
50	0.962059	0.272840	1.924118	0.545680	2.886177	0.818520	3.848236	1.091360	4.810295	1.364200	10
52	0.961900	0.273399	1.923800	0.546798	2.885700	0.820197	3.847600	1.093596	4.809500	1.366995	8
54	0.961741	0.273959	1.923482	0.547918	2.885223	0.821877	3.846964	1.095836	4.808705	1.369795	6
56	0.961581	0.274518	1.923162	0.549036	2.884743	0.823554	3.846324	1.098072	4.807905	1.372590	4
58	0.961421	0.275078	1.922842	0.550156	2.884263	0.825234	3.845684	1.100312	4.807105	1.375390	2′
60	0.961261	0.275637	1.922522	0.551274	2.883783	0.826911	3.845044	1.102548	4.806305	1.378185	74°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
16°	0.961261	0.275637	1.922522	0.551274	2.883783	0.826911	3.845044	1.102548	4.806305	1.378185	60'
2'	0.961101	0.276196	1.922202	0.552392	2.883303	0.828589	3.844404	1.104784	4.805505	1.380980	58
4	0.960940	0.276755	1.921880	0.553510	2.882820	0.830265	3.843760	1.107020	4.804700	1.383775	56
6	0.960779	0.277314	1.921558	0.554628	2.882337	0.831942	3.843116	1.109256	4.803895	1.386570	54
8	0.960617	0.277873	1.921234	0.555746	2.881851	0.833619	3.842468	1.111492	4.803085	1.389365	52
10	0.960455	0.278432	1.920910	0.556864	2.881365	0.835296	3.841820	1.113728	4.802275	1.392160	50
12	0.960293	0.278991	1.920586	0.557982	2.880879	0.836973	3.841172	1.115964	4.801465	1.394955	48
14	0.960131	0.279549	1.920262	0.559098	2.880393	0.838647	3.840524	1.118196	4.800655	1.397745	46
16	0.959968	0.280108	1.919936	0.560216	2.879904	0.840324	3.839872	1.120432	4.799840	1.400540	44
18	0.959805	0.280666	1.919610	0.561332	2.879416	0.841998	3.839220	1.122664	4.799025	1.403330	42
20	0.959641	0.281225	1.919282	0.562450	2.878923	0.843675	3.838564	1.124900	4.798205	1.406125	40
22	0.959478	0.281783	1.918956	0.563566	2.878434	0.845349	3.837912	1.127132	4.797390	1.408915	38
24	0.959314	0.282341	1.918628	0.564682	2.877942	0.847023	3.837256	1.129364	4.796570	1.411705	36
26	0.959149	0.282899	1.918298	0.565798	2.877447	0.848697	3.836596	1.131596	4.795745	1.414495	34
28	0.958984	0.283457	1.917968	0.566914	2.876952	0.850371	3.835936	1.133828	4.794920	1.417285	32
30	0.958819	0.284015	1.917638	0.568030	2.876457	0.852045	3.835276	1.136060	4.794095	1.420075	30
32	0.958654	0.284573	1.917308	0.569146	2.875962	0.853719	3.834616	1.138292	4.793270	1.422865	28
34	0.958488	0.285130	1.916976	0.570260	2.875464	0.855390	3.833952	1.140520	4.792440	1.425650	26
36	0.958322	0.285688	1.916644	0.571376	2.874966	0.857064	3.833288	1.142752	4.791610	1.428440	24
38	0.958156	0.286245	1.916312	0.572490	2.874468	0.858735	3.832624	1.144980	4.790780	1.431225	22
40	0.957989	0.286803	1.915978	0.573606	2.873967	0.860409	3.831956	1.147212	4.789945	1.434015	20
42	0.957822	0.287360	1.915644	0.574720	2.873466	0.862080	3.831288	1.149440	4.789110	1.436800	18
44	0.957655	0.287917	1.915310	0.575834	2.872965	0.863751	3.830620	1.151668	4.788275	1.439585	16
46	0.957487	0.288474	1.914974	0.576948	2.872461	0.865422	3.829948	1.153896	4.787435	1.442370	14
48	0.957319	0.289031	1.914638	0.578062	2.871957	0.867093	3.829276	1.156124	4.786595	1.445155	12
50	0.957151	0.289588	1.914302	0.579176	2.871453	0.868764	3.828604	1.158352	4.785755	1.447940	10
52	0.956982	0.290145	1.913964	0.580290	2.870946	0.870435	3.827928	1.160580	4.784910	1.450725	8
54	0.956813	0.290702	1.913626	0.581404	2.870439	0.872106	3.827252	1.162808	4.784065	1.453510	6
56	0.956644	0.291258	1.913288	0.582516	2.869932	0.873774	3.826576	1.165032	4.783220	1.456290	4
58	0.956477	0.291815	1.912954	0.583630	2.869431	0.875445	3.825908	1.167260	4.782385	1.459075	2
60	0.956304	0.292371	1.912608	0.584742	2.868912	0.877113	3.825216	1.169484	4.781520	1.461855	73°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
17°	0.956304	0.292371	1.912608	0.584742	2.868912	0.877113	3.825216	1.169484	4.781520	1.461855	60′
2′	0.956134	0.292928	1.912268	0.585856	2.868402	0.878784	3.824536	1.171712	4.780670	1.464640	58
4	0.955963	0.293454	1.911926	0.586908	2.867889	0.880452	3.823852	1.173936	4.779815	1.467420	56
6	0.955793	0.294040	1.911586	0.588080	2.867379	0.882120	3.823172	1.176160	4.778965	1.470200	54
8	0.955621	0.294596	1.911242	0.589192	2.866863	0.883788	3.822484	1.178384	4.778105	1.472980	52
10	0.955450	0.295152	1.910900	0.590304	2.866350	0.885456	3.821800	1.180608	4.777250	1.475760	50
12	0.955278	0.295708	1.910556	0.591416	2.865834	0.887124	3.821112	1.182832	4.776390	1.478541	48
14	0.955106	0.296263	1.910212	0.592526	2.865318	0.888789	3.820424	1.185052	4.775530	1.481315	46
16	0.954933	0.296819	1.909866	0.593638	2.864799	0.890457	3.819732	1.187276	4.774665	1.484095	44
18	0.954760	0.297374	1.909520	0.594748	2.864280	0.892122	3.819040	1.189496	4.773800	1.486870	42
20	0.954587	0.297930	1.909174	0.595860	2.863761	0.893790	3.818348	1.191720	4.772935	1.489650	40
22	0.954414	0.298485	1.908828	0.596970	2.863242	0.895455	3.817656	1.193940	4.772070	1.492425	38
24	0.954240	0.299040	1.908480	0.598080	2.862720	0.897120	3.816960	1.196160	4.771200	1.495200	36
26	0.954066	0.299595	1.908132	0.599190	2.862198	0.898785	3.816264	1.198380	4.770330	1.497975	34
28	0.953891	0.300150	1.907782	0.600300	2.861673	0.909450	3.815564	1.200600	4.769455	1.500750	32
30	0.953717	0.300705	1.907434	0.601410	2.861151	0.902115	3.814868	1.202820	4.768585	1.503525	30
32	0.953541	0.301260	1.907082	0.602520	2.860623	0.903780	3.814164	1.205040	4.767705	1.506300	28
34	0.953366	0.301815	1.906732	0.603630	2.860098	0.905445	3.813464	1.207262	4.766830	1.509075	26
36	0.953190	0.302369	1.906380	0.604738	2.859570	0.907107	3.812760	1.209476	4.765950	1.511845	24
38	0.953014	0.302924	1.906028	0.605848	2.859042	0.908772	3.812056	1.211696	4.765070	1.514620	22
40	0.952838	0.303478	1.905676	0.606956	2.858514	0.910434	3.811352	1.213912	4.764190	1.517390	20
42	0.952661	0.304033	1.905322	0.608066	2.857983	0.912099	3.810644	1.216132	4.763305	1.520165	18
44	0.952484	0.304587	1.904968	0.609174	2.857452	0.913761	3.809936	1.218348	4.762420	1.522935	16
46	0.952307	0.305141	1.904614	0.610282	2.856921	0.915423	3.809228	1.220564	4.761535	1.525705	14
48	0.952129	0.305695	1.904258	0.611390	2.856387	0.917085	3.808516	1.222780	4.760645	1.528475	12
50	0.951951	0.306249	1.903902	0.612498	2.855853	0.918747	3.807804	1.224996	4.759755	1.531245	10
52	0.951773	0.306803	1.903546	0.613606	2.855319	0.930409	3.807092	1.227212	4.758865	1.534015	8
54	0.951594	0.307356	1.903188	0.614712	2.854782	0.922068	3.806376	1.229424	4.757970	1.536780	6
56	0.951415	0.307910	1.902830	0.615820	2.854245	0.923730	3.805660	1.231640	4.757075	1.539550	4
58	0.951236	0.308463	1.902472	0.616926	2.853708	0.925389	3.804944	1.233852	4.756180	1.542315	2
60	0.951056	0.309017	1.902112	0.618034	2.853168	0.927051	3.804224	1.236068	4.755280	1.545085	72°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
18°	0.951056	0.309017	1.902112	0.618034	2.853168	0.927051	3.804224	1.236068	4.755280	1.545085	60′
2	0.950876	0.309570	1.901752	0.619140	2.852628	0.928710	3.803504	1.238280	4.754380	1.547850	58
4	0.950696	0.310123	1.901392	0.620246	2.852088	0.930369	3.802784	1.240492	4.753480	1.550615	56
6	0.950515	0.310676	1.901030	0.621352	2.851545	0.932018	3.802060	1.242704	4.752575	1.553330	54
8	0.950334	0.311229	1.900668	0.622458	2.851002	0.933687	3.801336	1.244916	4.751670	1.556145	52
10	0.950153	0.311782	1.900306	0.623564	2.850459	0.935346	3.800612	1.247128	4.750765	1.558910	50
12	0.949972	0.312334	1.899944	0.624668	2.849916	0.937002	3.799888	1.249336	4.749860	1.561670	48
14	0.949790	0.312887	1.899580	0.625774	2.849370	0.938661	3.799160	1.251548	4.748950	1.564435	46
16	0.949608	0.313440	1.899216	0.626880	2.848824	0.940320	3.798432	1.253760	4.748040	1.567200	44
18	0.949425	0.313992	1.898850	0.627934	2.848275	0.941976	3.797700	1.255968	4.747125	1.569960	42
20	0.949242	0.314544	1.898484	0.629088	2.847726	0.943632	3.796968	1.258176	4.746210	1.572720	40
22	0.949059	0.315096	1.898118	0.630192	2.847177	0.945288	3.796236	1.260384	4.745295	1.575480	38
24	0.948876	0.315649	1.897752	0.631298	2.846628	0.946947	3.795504	1.262596	4.744380	1.578245	36
26	0.948692	0.316200	1.897384	0.632400	2.846076	0.948600	3.794768	1.264800	4.743460	1.581005	34
28	0.948508	0.316752	1.897016	0.633504	2.845524	0.950256	3.794032	1.267008	4.742540	1.583760	32
30	0.948323	0.317304	1.896646	0.634608	2.844969	0.951912	3.793292	1.269216	4.741615	1.586520	30
32	0.948138	0.317856	1.896276	0.635712	2.844414	0.953568	3.792552	1.271424	4.740690	1.589280	28
34	0.947953	0.318407	1.895906	0.636804	2.843859	0.955221	3.791812	1.273628	4.739765	1.592035	26
36	0.947768	0.318959	1.895536	0.637918	2.843304	0.956877	3.791072	1.275836	4.738840	1.594795	24
38	0.947582	0.319510	1.895164	0.639020	2.842746	0.958530	3.790328	1.278040	4.737910	1.597550	22
40	0.947396	0.320061	1.894792	0.640122	2.842188	0.960183	3.789584	1.280244	4.736980	1.600305	20
42	0.947210	0.320613	1.894420	0.641226	2.841630	0.961839	3.788840	1.282452	4.736050	1.603065	18
44	0.947023	0.321164	1.894046	0.642328	2.841069	0.963492	3.788092	1.284656	4.735015	1.605820	16
46	0.946836	0.321714	1.893672	0.643428	2.840508	0.965142	3.787344	1.286856	4.734180	1.608570	14
48	0.946649	0.322265	1.893298	0.644530	2.840047	0.966795	3.786596	1.289060	4.733245	1.611325	12
50	0.946461	0.322816	1.892922	0.645632	2.839383	0.968448	3.785844	1.291264	4.732305	1.614080	10
52	0.946273	0.323367	1.892546	0.646734	2.839819	0.970101	3.785092	1.293468	4.731365	1.616835	8
54	0.946085	0.323917	1.892170	0.647834	2.838255	0.971751	3.784340	1.295668	4.730425	1.619585	6
56	0.945896	0.324467	1.891792	0.648934	2.837688	0.973401	3.783584	1.297868	4.729480	1.622335	4
58	0.945707	0.325018	1.891414	0.650036	2.837121	0.975054	3.782828	1.300072	4.728535	1.625090	2
60	0.945518	0.325568	1.891036	0.651136	2.836544	0.976704	3.782072	1.302272	4.727590	1.627840	71°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
19°	0.945518	0.325568	1.891036	0.651136	2.836554	0.976704	3.782072	1.302272	4.727590	1.627840	60′
2	0.945329	0.326118	1.890658	0.652236	2.835987	0.978354	3.781316	1.304472	4.726645	1.630590	58
4	0.945139	0.326668	1.890278	0.653336	2.835417	0.980004	3.780556	1.306672	4.725695	1.633340	56
6	0.944948	0.327217	1.889896	0.654434	2.834844	0.981651	3.779792	1.308868	4.724740	1.636085	54
8	0.944758	0.327767	1.889516	0.655534	2.834274	0.983301	3.779032	1.311068	4.723790	1.638835	52
10	0.944567	0.328317	1.889134	0.656634	2.833701	0.984951	3.778268	1.313268	4.722835	1.641585	50
12	0.944376	0.328866	1.888752	0.657732	2.833128	0.986598	3.777504	1.315464	4.721880	1.644330	48
14	0.944184	0.329416	1.888368	0.658832	2.832552	0.988248	3.776736	1.317664	4.720920	1.647080	46
16	0.943993	0.329965	1.887986	0.659930	2.831979	0.989895	3.775972	1.319860	4.719965	1.649825	44
18	0.943801	0.330514	1.887602	0.661028	2.831403	0.991542	3.775204	1.322056	4.719005	1.652570	42
20	0.943608	0.331063	1.887216	0.662126	2.830824	0.993189	3.774432	1.324252	4.718040	1.655315	40
22	0.943415	0.331612	1.886830	0.663224	2.830245	0.994836	3.773660	1.326448	4.717075	1.658060	38
24	0.943222	0.332161	1.886444	0.664322	2.829666	0.996483	3.772888	1.328644	4.716110	1.660805	36
26	0.943029	0.332709	1.886058	0.665418	2.829087	0.998127	3.772116	1.330836	4.715145	1.663545	34
28	0.942835	0.333258	1.885670	0.666516	2.828505	0.999774	3.771340	1.333032	4.714175	1.666290	32
30	0.942641	0.333806	1.885282	0.667612	2.827923	1.001418	3.770564	1.335224	4.713205	1.669030	30
32	0.942447	0.334355	1.884894	0.668710	2.827341	1.003065	3.769788	1.337420	4.712235	1.671775	28
34	0.942252	0.334903	1.884504	0.669806	2.826756	1.004709	3.769008	1.339612	4.711260	1.674515	26
36	0.942057	0.335451	1.884114	0.670902	2.826171	1.006353	3.768228	1.341804	4.710285	1.677255	24
38	0.941862	0.335999	1.883724	0.671998	2.825586	1.007997	3.767448	1.343996	4.709310	1.679995	22
40	0.941666	0.336547	1.883332	0.673094	2.824998	1.009641	3.766664	1.346188	4.708330	1.682735	20
42	0.941470	0.337095	1.882940	0.674190	2.824410	1.011285	3.765880	1.348380	4.707350	1.685475	18
44	0.941274	0.337642	1.882548	0.675284	2.823822	1.012926	3.765096	1.350568	4.706370	1.688210	16
46	0.941077	0.338190	1.882154	0.676380	2.823231	1.014570	3.764308	1.352760	4.705385	1.690950	14
48	0.940880	0.338737	1.881760	0.677474	2.822640	1.016211	3.763520	1.354948	4.704400	1.693685	12
50	0.940683	0.339285	1.881366	0.678570	2.822049	1.017855	3.762732	1.357140	4.703415	1.696425	10
52	0.940486	0.339832	1.880972	0.679664	2.821458	1.019496	3.761944	1.359328	4.702430	1.699160	8
54	0.940288	0.340379	1.880576	0.680758	2.820864	1.021137	3.761152	1.361516	4.701440	1.701895	6
56	0.940089	0.340926	1.880178	0.681852	2.820267	1.022778	3.760356	1.363704	4.700445	1.704630	4
58	0.939891	0.341473	1.879782	0.682946	2.819673	1.024419	3.759564	1.365892	4.699455	1.707365	2
60	0.939692	0.342020	1.879384	0.684040	2.819076	1.026060	3.758768	1.368080	4.698460	1.710100	70°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse. 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
20°	0.939692	0.342020	1.879384	0.684040	2.819076	1.026060	3.758768	1.368080	4.698460	1.710100	60′
2′	0.939493	0.342566	1.878986	0.685132	2.818479	1.027698	3.757972	1.370264	4.697465	1.712830	58
4	0.939294	0.343113	1.878588	0.686226	2.817882	1.029339	3.757176	1.372452	4.696470	1.715565	56
6	0.939094	0.343659	1.878188	0.687318	2.817282	1.030977	3.756376	1.374636	4.695470	1.718295	54
8	0.938894	0.344206	1.877788	0.688412	2.816682	1.032618	3.755576	1.376824	4.694470	1.721030	52
10	0.938693	0.344752	1.877386	0.689504	2.816079	1.034256	3.754762	1.379008	4.693465	1.723760	50
12	0.938493	0.345298	1.876986	0.690596	2.815479	1.035894	3.753972	1.381192	4.692465	1.726490	48
14	0.938292	0.345844	1.876584	0.691688	2.814876	1.037532	3.753168	1.383376	4.691460	1.729220	46
16	0.938090	0.346390	1.876180	0.692780	2.814270	1.039170	3.752360	1.385560	4.690450	1.731950	44
18	0.937888	0.346935	1.875776	0.693870	2.813664	1.040805	3.751552	1.387740	4.689440	1.734675	42
20	0.937686	0.347481	1.875372	0.694962	2.813058	1.042443	3.750744	1.389924	4.688430	1.737405	40
22	0.937484	0.348026	1.874968	0.696052	2.812452	1.044078	3.749936	1.392104	4.687420	1.740130	38
24	0.937282	0.348572	1.874564	0.697144	2.811846	1.045716	3.749128	1.394288	4.686410	1.742860	36
26	0.937079	0.349117	1.874158	0.698234	2.811237	1.047341	3.748316	1.396468	4.685395	1.745585	34
28	0.936875	0.349662	1.873750	0.699324	2.810625	1.048986	3.747500	1.398648	4.684375	1.748310	32
30	0.936672	0.350207	1.873344	0.700414	2.810016	1.050621	3.746688	1.400828	4.683360	1.751035	30
32	0.936468	0.350752	1.872936	0.701504	2.809404	1.052256	3.745872	1.403008	4.682340	1.753760	28
34	0.936264	0.351297	1.872528	0.702594	2.808792	1.053891	3.745056	1.405188	4.681320	1.756485	26
36	0.936059	0.351841	1.872118	0.703682	2.808177	1.055523	3.744236	1.407364	4.680295	1.759205	24
38	0.935854	0.352386	1.871708	0.704772	2.807562	1.057158	3.743416	1.409544	4.679270	1.761930	22
40	0.935649	0.352930	1.871298	0.705860	2.806947	1.058790	3.742596	1.411720	4.678245	1.764650	20
42	0.935444	0.353474	1.870888	0.706948	2.806332	1.060422	3.741776	1.413896	4.677220	1.767370	18
44	0.935238	0.354019	1.870476	0.708038	2.805714	1.062057	3.740952	1.416076	4.676190	1.770095	16
46	0.935032	0.354563	1.870064	0.709126	2.805096	1.063689	3.740128	1.418252	4.675160	1.772815	14
48	0.934825	0.355107	1.869650	0.710214	2.804475	1.065321	3.739300	1.420428	4.674125	1.775535	12
50	0.934618	0.355650	1.869236	0.711300	2.803854	1.066950	3.738472	1.422600	4.673090	1.778250	10
52	0.934411	0.356194	1.868822	0.712388	2.803233	1.068582	3.737644	1.424776	4.672055	1.780970	8
54	0.934204	0.356738	1.868408	0.713476	2.802612	1.070214	3.736816	1.426952	4.671020	1.783690	6
56	0.933996	0.357281	1.867992	0.714562	2.801988	1.071843	3.735984	1.429124	4.669980	1.786405	4
58	0.933788	0.357824	1.867576	0.715648	2.801364	1.073472	3.735152	1.431296	4.668940	1.789120	2
60	0.933580	0.358367	1.867160	0.716734	2.800740	1.075101	3.734320	1.433468	4.667900	1.791835	69°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
21°	0.933580	0.358367	1.867160	0.716734	2.800740	1.075101	3.734320	1.433468	4.667900	1.791835	60'
2	0.933371	0.358911	1.866742	0.717822	2.800113	1.076733	3.733484	1.435644	4.666855	1.794555	58
4	0.933162	0.359454	1.866324	0.718908	2.799486	1.078362	3.732648	1.437816	4.665810	1.797270	56
6	0.932953	0.359996	1.865906	0.719992	2.798859	1.079988	3.731812	1.439984	4.664765	1.799980	54
8	0.932743	0.360539	1.865486	0.721078	2.798229	1.081617	3.730972	1.442156	4.663715	1.802695	52
10	0.932534	0.361082	1.865068	0.722164	2.797602	1.083246	3.730136	1.444328	4.662670	1.805410	50
12	0.932323	0.361624	1.864646	0.723248	2.796969	1.084872	3.729292	1.446496	4.661615	1.808120	48
14	0.932113	0.362166	1.864226	0.724332	2.796339	1.086498	3.728452	1.448664	4.660565	1.810830	46
16	0.931902	0.362709	1.863804	0.725418	2.795706	1.088127	3.727608	1.450836	4.659510	1.813545	44
18	0.931691	0.363251	1.863382	0.726502	2.795073	1.089753	3.726764	1.453004	4.658455	1.816255	42
20	0.931479	0.363793	1.862958	0.727586	2.794437	1.091379	3.725916	1.455172	4.657395	1.818965	40
22	0.931267	0.364335	1.862534	0.728670	2.793801	1.093005	3.725068	1.457340	4.656335	1.821675	38
24	0.931055	0.364876	1.862110	0.729752	2.793165	1.094628	3.724220	1.459504	4.655275	1.824380	36
26	0.930843	0.365418	1.861686	0.730836	2.792529	1.096254	3.723372	1.461672	4.654215	1.827090	34
28	0.930630	0.365959	1.861260	0.731918	2.791890	1.097877	3.722520	1.463836	4.653150	1.829795	32
30	0.930417	0.366501	1.860834	0.733002	2.791251	1.099503	3.721668	1.466004	4.652085	1.832505	30
32	0.930204	0.367042	1.860408	0.734084	2.790612	1.101126	3.720816	1.468168	4.651020	1.835210	28
34	0.929990	0.367583	1.859980	0.735166	2.789970	1.102749	3.719960	1.470332	4.649950	1.837915	26
36	0.929776	0.368124	1.859552	0.736248	2.789328	1.104372	3.719104	1.472496	4.648880	1.840620	24
38	0.929562	0.368665	1.859124	0.737330	2.788686	1.105995	3.718248	1.474660	4.647810	1.843325	22
40	0.929347	0.369206	1.858694	0.738412	2.788041	1.107618	3.717388	1.476824	4.646735	1.846030	20
42	0.929132	0.369746	1.858264	0.739492	2.787396	1.109238	3.716528	1.478984	4.645660	1.848730	18
44	0.928917	0.370287	1.857834	0.740574	2.786751	1.110861	3.715668	1.481148	4.644585	1.851435	16
46	0.928701	0.370827	1.857402	0.741654	2.786103	1.112481	3.714804	1.483308	4.643505	1.854135	14
48	0.928485	0.371367	1.856970	0.742734	2.785455	1.114101	3.713940	1.485468	4.642425	1.856835	12
50	0.928269	0.371907	1.856538	0.743814	2.784807	1.115721	3.713076	1.487628	4.641345	1.859535	10
52	0.928053	0.372447	1.856106	0.744894	2.784159	1.117341	3.712212	1.489788	4.640265	1.862235	8
54	0.927836	0.372987	1.855672	0.745974	2.783508	1.118961	3.711344	1.491948	4.639180	1.864935	6
56	0.927619	0.373527	1.855238	0.747054	2.782857	1.120581	3.710476	1.494108	4.638095	1.867635	4
58	0.927401	0.374067	1.854802	0.748134	2.782203	1.122201	3.709604	1.496268	4.637005	1.870335	2
60	0.927183	0.374606	1.854366	0.749212	2.781549	1.123818	3.708732	1.498424	4.635915	1.873030	68°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
22°	0.927183	0.374606	1.854366	0.749212	2.781549	1.123818	3.708732	1.498424	4.635915	1.873030	60′
2′	0.926965	0.375145	1.853930	0.750290	2.780895	1.125435	3.707860	1.500580	4.634825	1.875725	58
4	0.926747	0.375685	1.853494	0.751370	2.780241	1.127055	3.706988	1.502740	4.633735	1.878425	56
6	0.926528	0.376224	1.853056	0.752448	2.779584	1.128672	3.706112	1.504896	4.632640	1.881120	54
8	0.926309	0.376763	1.852618	0.753526	2.778927	1.130289	3.705236	1.507052	4.631545	1.883815	52
10	0.926090	0.377302	1.852180	0.754604	2.778270	1.131906	3.704360	1.509208	4.630450	1.886510	50
12	0.925870	0.377840	1.851740	0.755680	2.777610	1.133520	3.703480	1.511360	4.629350	1.889200	48
14	0.925650	0.378379	1.851300	0.756758	2.776950	1.135137	3.702600	1.513516	4.628250	1.891895	46
16	0.925430	0.378917	1.850860	0.757834	2.776290	1.136751	3.701720	1.515678	4.627150	1.894585	44
18	0.925209	0.379456	1.850418	0.758912	2.775627	1.138368	3.700836	1.517824	4.626045	1.897280	42
20	0.924988	0.379994	1.849976	0.759988	2.774964	1.139982	3.699952	1.519976	4.624940	1.899970	40
22	0.924767	0.380532	1.849534	0.761064	2.774301	1.141596	3.699068	1.522128	4.623835	1.902660	38
24	0.924546	0.381074	1.849092	0.762148	2.773638	1.143222	3.698184	1.524296	4.622730	1.905370	36
26	0.924324	0.381608	1.848648	0.763216	2.772972	1.144824	3.697296	1.526432	4.621620	1.908040	34
28	0.924102	0.382145	1.848204	0.764290	2.772306	1.146435	3.696408	1.528580	4.620510	1.910725	32
30	0.923879	0.382683	1.847758	0.765366	2.771637	1.148049	3.695516	1.530732	4.619395	1.913415	30
32	0.923656	0.383220	1.847312	0.766440	2.770968	1.149660	3.694624	1.532886	4.618280	1.916100	28
34	0.923433	0.383758	1.846866	0.767516	2.770299	1.151274	3.693732	1.535032	4.617165	1.918790	26
36	0.923210	0.384295	1.846420	0.768590	2.769630	1.152885	3.692840	1.537180	4.616050	1.921475	24
38	0.922986	0.384822	1.845972	0.769644	2.768958	1.154466	3.691944	1.539288	4.614930	1.924110	22
40	0.922762	0.385369	1.845524	0.770738	2.768286	1.156107	3.691048	1.541476	4.613810	1.926845	20
42	0.922538	0.385906	1.845076	0.771812	2.767614	1.157718	3.690152	1.543624	4.612690	1.929530	18
44	0.922313	0.386442	1.844626	0.772884	2.766939	1.159326	3.689252	1.545768	4.611565	1.932210	16
46	0.922088	0.386979	1.844176	0.773958	2.766264	1.160937	3.688352	1.547916	4.610440	1.934895	14
48	0.921863	0.387515	1.843726	0.775030	2.765589	1.162545	3.687452	1.550060	4.609315	1.937595	12
50	0.921637	0.388051	1.843274	0.776102	2.764911	1.164153	3.686548	1.552204	4.608185	1.940255	10
52	0.921411	0.388588	1.842822	0.777176	2.764233	1.165764	3.685644	1.554352	4.607055	1.942940	8
54	0.921185	0.389124	1.842370	0.778248	2.763555	1.167372	3.684740	1.556496	4.605925	1.945620	6
56	0.920958	0.389659	1.841916	0.779318	2.762874	1.168977	3.683832	1.558636	4.604790	1.948295	4
58	0.920732	0.390195	1.841464	0.780390	2.762196	1.170585	3.682928	1.560780	4.603660	1.950975	2
60	0.920504	0.390731	1.841008	0.781462	2.761512	1.172193	3.682016	1.562924	4.602520	1.953655	67°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
23	0.920504	0.390731	1.841008	0.781462	2.761512	1.172193	3.682016	1.562924	4.602520	1.953655	60'
2'	0.920277	0.391266	1.840554	0.782532	2.760831	1.173798	3.681108	1.565064	4.601385	1.956330	58
4	0.920049	0.391801	1.840098	0.783602	2.760147	1.175403	3.680196	1.567204	4.600245	1.959005	56
6	0.919821	0.392337	1.839642	0.784674	2.759463	1.177011	3.679284	1.569348	4.599106	1.961685	54
8	0.919593	0.392872	1.839186	0.785744	2.758779	1.178616	3.678372	1.571488	4.597965	1.964360	52
10	0.919364	0.393407	1.838728	0.786814	2.758092	1.180221	3.677456	1.573628	4.596820	1.967035	50
12	0.919135	0.393941	1.838270	0.787882	2.757405	1.181823	3.676540	1.575764	4.595675	1.969705	48
14	0.918906	0.394476	1.837812	0.788952	2.756718	1.183428	3.675624	1.577904	4.594530	1.972380	46
16	0.918676	0.395011	1.837352	0.790022	2.756028	1.185033	3.674704	1.580044	4.593380	1.975055	44
18	0.918446	0.395545	1.836892	0.791090	2.755338	1.186635	3.673784	1.582180	4.592230	1.977725	42
20	0.918216	0.396079	1.836432	0.792158	2.754648	1.188227	3.672864	1.584316	4.591080	1.980395	40
22	0.917985	0.396613	1.835970	0.793226	2.753955	1.189839	3.671940	1.586452	4.589925	1.983065	38
24	0.917754	0.397147	1.835508	0.794294	2.753262	1.191441	3.671016	1.588588	4.588770	1.985735	36
26	0.917523	0.397681	1.835046	0.795362	2.752569	1.193043	3.670092	1.590724	4.587615	1.988405	34
28	0.917291	0.398215	1.834582	0.796430	2.751873	1.194645	3.669164	1.592866	4.586455	1.991075	32
30	0.917060	0.398749	1.834120	0.797498	2.751180	1.196247	3.668240	1.594996	4.585300	1.993745	30
32	0.916827	0.399282	1.833654	0.798564	2.750481	1.197846	3.667308	1.597128	4.584135	1.996410	28
34	0.916595	0.399815	1.833190	0.799630	2.749785	1.199445	3.666380	1.599260	4.582975	1.999075	26
36	0.916362	0.400349	1.832724	0.800698	2.749086	1.201047	3.665448	1.601396	4.581810	2.001745	24
38	0.916129	0.400882	1.832258	0.801764	2.748387	1.202646	3.664516	1.603528	4.580645	2.004410	22
40	0.915896	0.401415	1.831792	0.802830	2.747688	1.204245	3.663584	1.605660	4.579480	2.007075	20
42	0.915662	0.401947	1.831324	0.803894	2.746986	1.205841	3.662648	1.607788	4.578310	2.009735	18
44	0.915428	0.402480	1.830856	0.804960	2.746284	1.207440	3.661712	1.609920	4.577140	2.012400	16
46	0.915196	0.403012	1.830392	0.806024	2.745588	1.209036	3.660784	1.612048	4.575980	2.015060	14
48	0.914959	0.403545	1.829918	0.807090	2.744877	1.210635	3.659836	1.614180	4.574796	2.017725	12
50	0.914724	0.404077	1.829448	0.808154	2.744172	1.212231	3.658896	1.616308	4.573620	2.020385	10
52	0.914489	0.404609	1.828978	0.809218	2.743467	1.213827	3.657956	1.618436	4.572445	2.023045	8
54	0.914254	0.405141	1.828508	0.810282	2.742762	1.215423	3.657016	1.620564	4.571270	2.025705	6
56	0.914018	0.405673	1.828036	0.811346	2.742054	1.217019	3.656072	1.622692	4.570090	2.028365	4
58	0.913781	0.406205	1.827562	0.812410	2.741343	1.218615	3.655124	1.624820	4.568905	2.031025	2
60	0.913545	0.406736	1.827090	0.813472	2.740635	1.220208	3.654180	1.626944	4.567725	2.033680	66°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
24°	0.913545	0.406736	1.827090	0.813472	2.740635	1.220208	3.654180	1.626944	4.567725	2.033680	60′
2′	0.913308	0.407268	1.826616	0.814536	2.739924	1.221804	3.653232	1.629072	4.566540	2.036340	58
4	0.913071	0.407799	1.826142	0.815598	2.739213	1.223397	3.652284	1.631196	4.565355	2.038995	56
6	0.912834	0.408330	1.825668	0.816660	2.738502	1.224990	3.651336	1.633320	4.564170	2.041651	54
8	0.912596	0.408861	1.825192	0.817722	2.737788	1.226583	3.650384	1.635444	4.562980	2.044305	52
10	0.912358	0.409392	1.824716	0.818784	2.737074	1.228176	3.649432	1.637568	4.562790	2.046960	50
12	0.912120	0.409923	1.824240	0.819846	2.736360	1.229769	3.648480	1.639692	4.560600	2.049615	48
14	0.911881	0.410453	1.823762	0.820906	2.735643	1.231359	3.647524	1.641812	4.559405	2.052265	46
16	0.911642	0.410984	1.823284	0.821968	2.734926	1.232952	3.646568	1.643936	4.558210	2.054920	44
18	0.911403	0.411514	1.822806	0.822028	2.734209	1.234542	3.645612	1.644056	4.557015	2.057570	42
20	0.911163	0.412044	1.822326	0.824088	2.733489	1.236132	3.644652	1.648176	4.555815	2.060220	40
22	0.910923	0.412574	1.821846	0.825148	2.732769	1.237722	3.643692	1.650296	4.554615	2.062870	38
24	0.910683	0.413104	1.821366	0.826208	2.732049	1.239312	3.642732	1.652416	4.553415	2.065520	36
26	0.910443	0.413634	1.820886	0.827268	2.731329	1.240902	3.641772	1.654536	4.552215	2.068170	34
28	0.910202	0.414163	1.820404	0.828326	2.730606	1.242489	3.640808	1.656652	4.551010	2.070815	32
30	0.909961	0.414693	1.819922	0.829386	2.729883	1.244079	3.639844	1.658772	4.549805	2.073465	30
32	0.909719	0.415222	1.819438	0.830444	2.729157	1.245666	3.638876	1.660888	4.548595	2.076110	28
34	0.909478	0.415751	1.818956	0.831502	2.728434	1.247253	3.637912	1.663004	4.547390	2.078755	26
36	0.909236	0.416280	1.818472	0.832560	2.727708	1.248840	3.636944	1.665120	4.546180	2.081400	24
38	0.908993	0.416809	1.817986	0.833618	2.726979	1.250427	3.635972	1.667236	4.544965	2.084045	22
40	0.908751	0.417338	1.817502	0.834676	2.726253	1.252014	3.635004	1.669352	4.543755	2.086690	20
42	0.908508	0.417867	1.817016	0.835734	2.725524	1.253601	3.634032	1.671468	4.542540	2.089335	18
44	0.908264	0.418395	1.816528	0.836790	2.724792	1.255185	3.633056	1.673560	4.541320	2.091975	16
46	0.908021	0.418923	1.816042	0.837846	2.724063	1.256769	3.632084	1.675692	4.540105	2.094615	14
48	0.907777	0.419452	1.815554	0.838904	2.723331	1.258356	3.631108	1.677808	4.538885	2.097260	12
50	0.907533	0.419980	1.815066	0.839960	2.722599	1.259940	3.630132	1.679920	4.537665	2.099900	10
52	0.907288	0.420508	1.814576	0.841016	2.721864	1.261524	3.629152	1.682032	4.536440	2.102540	8
54	0.907044	0.421035	1.814088	0.842070	2.721133	1.263105	3.628176	1.684140	4.535220	2.105175	6
56	0.906798	0.421563	1.813596	0.843126	2.720394	1.264689	3.627192	1.686252	4.533990	2.107815	4
58	0.906553	0.422090	1.813106	0.844180	2.719659	1.266270	3.626212	1.688360	4.532765	2.110450	2
60	0.906307	0.422618	1.812614	0.845236	2.718921	1.267854	3.625228	1.690472	4.531535	2.113090	65°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
25°	0.906307	0.422618	1.812614	0.845236	2.718921	1.267854	3.625228	1.690472	4.531535	2.113090	60′
2′	0.906061	0.423145	1.812122	0.846290	2.718183	1.269435	3.624244	1.692580	4.530305	2.115725	58
4	0.905815	0.423672	1.811630	0.847344	2.717445	1.271016	3.623260	1.694688	4.529075	2.118360	56
6	0.905568	0.424199	1.811136	0.848398	2.716704	1.272597	3.622272	1.696796	4.527840	2.120995	54
8	0.905321	0.424726	1.810642	0.849452	2.715963	1.274178	3.621284	1.698904	4.526605	2.123630	52
10	0.905074	0.425252	1.810148	0.850504	2.715222	1.275756	3.620296	1.701008	4.525370	2.126260	50
12	0.904827	0.425779	1.809654	0.851558	2.714481	1.277337	3.619308	1.703116	4.524135	2.128895	48
14	0.904579	0.426305	1.809158	0.852610	2.713737	1.278915	3.618316	1.705220	4.522895	2.131525	46
16	0.904331	0.426831	1.808662	0.853662	2.712993	1.280493	3.617324	1.707324	4.521655	2.134155	44
18	0.904082	0.427357	1.808164	0.854714	2.712246	1.282071	3.616328	1.709428	4.520410	2.136785	42
20	0.903833	0.427883	1.807666	0.855766	2.711499	1.283649	3.615332	1.711532	4.519165	2.139415	40
22	0.903584	0.428409	1.807168	0.856818	2.710752	1.285227	3.614336	1.713636	4.517920	2.142045	38
24	0.903335	0.428935	1.806670	0.857870	2.710005	1.286805	3.613340	1.715740	4.516675	2.144675	36
26	0.903085	0.429460	1.806170	0.858920	2.709255	1.288380	3.612340	1.717840	4.515425	2.147300	34
28	0.902835	0.429985	1.805670	0.859970	2.708505	1.289955	3.611340	1.719940	4.514175	2.149925	32
30	0.902585	0.430511	1.805170	0.861022	2.707755	1.291533	3.610340	1.722044	4.512925	2.152555	30
32	0.902334	0.431036	1.804668	0.862072	2.707002	1.293108	3.609336	1.724144	4.511670	2.155180	28
34	0.902083	0.431561	1.804166	0.863122	2.706249	1.294683	3.608332	1.726244	4.510415	3.157805	26
36	0.901832	0.432085	1.803664	0.864170	2.705496	1.296255	3.607328	1.728340	4.509160	2.160425	24
38	0.901581	0.432610	1.803162	0.865220	2.704743	1.297830	3.606324	1.730440	4.507905	2.163050	22
40	0.901329	0.433134	1.802658	0.866268	2.713987	1.299402	3.605316	1.732536	4.506645	2.165670	20
42	0.901077	0.433659	1.802154	0.867318	2.703231	1.300977	3.604308	1.734636	4.505385	2.168295	18
44	0.900824	0.434183	1.801648	0.868366	2.702472	1.302549	3.603296	1.736732	4.504120	2.170915	16
46	0.900571	0.434707	1.801142	0.869414	2.701713	1.304121	3.602284	1.738828	4.502855	2.173535	14
48	0.900318	0.435231	1.800636	0.870462	2.700954	1.305693	3.601272	1.740924	4.501590	2.176155	12
50	0.900065	0.435754	1.800130	0.871508	2.700195	1.307262	3.600260	1.743016	4.500325	2.178770	10
52	0.899811	0.436278	1.799622	0.872556	2.699433	1.408834	3.599244	1.745112	4.499055	2.181390	8
54	0.899557	0.436801	1.799114	0.873602	2.698671	1.410403	3.598228	1.747204	4.497785	2.184005	6
56	0.899303	0.437325	1.798606	0.874650	2.697909	1.411975	3.597212	1.749300	4.496515	2.186625	4
58	0.899048	0.437848	1.798096	0.875696	2.697144	1.313544	3.596192	1.751392	4.495240	2.189240	2
60	0.898794	0.438371	1.797588	0.876742	2.696382	1.315113	3.595176	1.753484	4.493970	2.191855	64°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
26°	0.898794	0.438371	1.797588	0.876742	2.696382	1.315113	3.595176	1.753484	4.493970	2.191855	60′
2′	0.898538	0.438894	1.797076	0.877788	2.695614	1.316682	3.594152	1.755576	4.492690	2.194470	58
4	0.898283	0.439416	1.796568	0.878832	2.694849	1.318248	3.593132	1.757664	4.491415	2.197080	56
6	0.898027	0.439939	1.796054	0.879878	2.694081	1.319817	3.592108	1.759756	4.490135	2.199695	54
8	0.897771	0.440461	1.795542	0.880922	2.693313	1.321383	3.591084	1.761844	4.488855	2.202305	52
10	0.897515	0.440983	1.795030	0.881966	2.692545	1.322949	3.590060	1.763932	4.487575	2.204915	50
12	0.897258	0.441505	1.794516	0.883010	2.691774	1.324515	3.589032	1.766020	4.486290	2.207525	48
14	0.897001	0.442027	1.794002	0.884054	2.691003	1.326081	3.588004	1.768108	4.485005	2.210135	46
16	0.896744	0.442549	1.793488	0.885093	2.690213	1.327647	3.586976	1.770196	4.483720	2.212745	44
18	0.896486	0.443071	1.792972	0.886142	2.689458	1.329213	3.585944	1.772284	4.482430	2.215355	42
20	0.896228	0.443592	1.792456	0.887184	2.688684	1.330776	3.584912	1.774368	4.481140	2.217960	40
22	0.895970	0.444114	1.791940	0.888228	2.687910	1.332342	3.583880	1.776456	4.479850	2.220570	38
24	0.895711	0.444635	1.791422	0.889270	2.687133	1.333905	3.582844	1.778540	4.478555	2.223175	36
26	0.895452	0.445156	1.790904	0.890312	2.686356	1.335468	3.581808	1.780624	4.477260	2.225780	34
28	0.895193	0.445677	1.790386	0.891354	2.685579	1.337031	3.580772	1.782708	4.475965	2.228385	32
30	0.894934	0.446197	1.789868	0.892394	2.684802	1.338591	3.579736	1.784788	4.474670	2.230985	30
32	0.894674	0.446718	1.789348	0.893436	2.684022	1.340154	3.578696	1.786872	4.473370	2.233590	28
34	0.894414	0.447238	1.788828	0.894476	2.683242	1.341714	3.577656	1.788952	4.472070	2.236190	26
36	0.894154	0.447759	1.788308	0.895518	2.682462	1.343277	3.576616	1.791036	4.470770	2.238795	24
38	0.893893	0.448279	1.787786	0.896558	2.681679	1.344837	3.575572	1.793116	4.469465	2.241395	22
40	0.893632	0.448799	1.787264	0.897598	2.680896	1.346397	3.574528	1.795196	4.468160	2.243995	20
42	0.893371	0.449319	1.786742	0.898638	2.680113	1.347957	3.573484	1.797276	4.466855	2.246595	18
44	0.893109	0.449838	1.786218	0.899676	2.679327	1.349514	3.572436	1.799352	4.465545	2.249190	16
46	0.892848	0.450358	1.785696	0.900716	2.678544	1.351074	3.571392	1.801432	4.464240	2.251790	14
48	0.892585	0.450877	1.785170	0.901754	2.677755	1.352631	3.570340	1.803508	4.462925	2.254385	12
50	0.892323	0.451396	1.784646	0.902792	2.676969	1.354188	3.569292	1.805584	4.461615	2.256980	10
52	0.892060	0.451915	1.784120	0.903830	2.676180	1.355745	3.568240	1.807660	4.460300	2.259575	8
54	0.891797	0.452434	1.783594	0.904863	2.675391	1.357302	3.567188	1.809736	4.458985	2.262170	6
56	0.891534	0.452953	1.783068	0.905906	2.674602	1.358859	3.566136	1.801812	4.457670	2.264765	4
58	0.891270	0.453472	1.782540	0.906944	2.673810	1.360416	3.565080	1.813858	4.456350	2.267360	2
60	0.891006	0.453990	1.782012	0.907980	2.673018	1.361970	3.564024	1.815960	4.455030	2.269950	63°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
27°	0.891006	0.453990	1.782012	0.907980	2.673018	1.361970	3.564024	1.815960	4.455030	2.269950	60′
2	0.890742	0.454508	1.781484	0.909016	2.672226	1.363524	3.562968	1.818032	4.453710	2.272540	58
4	0.890477	0.455026	1.780954	0.910052	2.671431	1.365078	3.561908	1.820104	4.452385	2.275130	56
6	0.890212	0.455544	1.780424	0.911088	2.670636	1.366632	3.560848	1.822176	4.451060	2.277720	54
8	0.889947	0.456062	1.779894	0.912124	2.669841	1.368186	3.559788	1.824248	4.449735	2.280310	52
10	0.889682	0.456580	1.779364	0.913160	2.669046	1.369740	3.558728	1.826320	4.448410	2.282900	50
12	0.889416	0.457097	1.778832	0.914194	2.668248	1.371291	3.557664	1.825388	4.447080	2.285485	48
14	0.889150	0.457615	1.778300	0.915230	2.667450	1.372845	3.556600	1.830460	4.445750	2.288075	46
16	0.888883	0.458132	1.777766	0.916264	2.666649	1.374396	3.555532	1.832528	4.444415	2.290660	44
18	0.888617	0.458649	1.777234	0.917298	2.665851	1.375947	3.554468	1.834596	4.443085	2.293245	42
20	0.888350	0.459166	1.776700	0.918332	2.665050	1.377498	3.553400	1.836664	4.441750	2.295830	40
22	0.888083	0.459683	1.776166	0.919366	2.664249	1.379049	3.552332	1.838732	4.440415	2.298415	38
24	0.887815	0.460199	1.775630	0.920398	2.663445	1.380597	3.551260	1.840796	4.439075	2.300995	36
26	0.887547	0.460716	1.775094	0.921432	2.662641	1.382148	3.550188	1.842864	4.437735	2.303580	34
28	0.887279	0.461232	1.774558	0.922464	2.661837	1.383696	3.549116	1.844928	4.436395	2.306160	32
30	0.887010	0.461748	1.774020	0.923496	2.661030	1.385244	3.548040	1.846992	4.435050	2.308740	30
32	0.886742	0.462264	1.773484	0.924528	2.660226	1.386792	3.546968	1.849056	4.433710	2.311320	28
34	0.886473	0.462780	1.772946	0.925560	2.659419	1.388340	3.545892	1.851120	4.432365	2.313900	26
36	0.886203	0.463296	1.772406	0.926592	2.658609	1.389888	3.544812	1.853184	4.431015	2.316480	24
38	0.885933	0.463811	1.771866	0.927622	2.657799	1.391433	3.543732	1.855244	4.429665	2.319055	22
40	0.885663	0.464326	1.771326	0.928652	2.656989	1.392978	3.542652	1.857304	4.428315	2.321630	20
42	0.885393	0.464842	1.770786	0.929684	2.656179	1.394526	3.541572	1.859368	4.426065	2.324210	18
44	0.885123	0.465357	1.770246	0.930714	2.655369	1.396171	3.540492	1.861428	4.425615	2.326785	16
46	0.884852	0.465871	1.769704	0.931742	2.654556	1.397613	3.539408	1.863484	4.424260	2.329355	14
48	0.884581	0.466386	1.769162	0.932772	2.653743	1.399158	3.538324	1.865544	4.422905	2.331930	12
50	0.884309	0.466901	1.768618	0.933802	2.652927	1.400703	3.537236	1.867604	4.421545	2.334505	10
52	0.884037	0.467415	1.768074	0.934830	2.652111	1.402245	3.536148	1.869660	4.420185	2.337075	8
54	0.883765	0.467929	1.767530	0.935858	2.651295	1.403787	3.535060	1.871716	4.418825	2.339645	6
56	0.883493	0.468443	1.766986	0.936886	2.650479	1.405329	3.533972	1.873772	4.417465	2.342215	4
58	0.883220	0.468957	1.766440	0.937914	2.649660	1.406871	3.532880	1.875828	4.416100	2.344785	2
60	0.882947	0.469471	1.765894	0.938942	2.648841	1.408413	3.531788	1.877884	4.414735	2.347355	62°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
28°	0.882947	0.469471	1.765894	0.938942	2.648841	1.408413	3.531788	1.877884	4.414735	2.347855	60'
2'	0.882674	0.469985	1.765348	0.939970	2.648022	1.409955	3.530696	1.879940	4.413370	2.349925	58
4	0.882400	0.470498	1.764800	0.940996	2.647200	1.411494	3.529600	1.891992	4.412000	2.352490	56
6	0.882126	0.471011	1.764252	0.942022	2.646378	1.413033	3.528504	1.884044	4.410630	2.355055	54
8	0.881852	0.471525	1.763704	0.943050	2.645556	1.414575	3.527408	1.886100	4.409260	2.3.7625	52
10	0.881578	0.472038	1.763156	0.944076	2.644734	1.416114	3.526312	1.888152	4.407890	2.360190	50
12	0.881303	0.472550	1.762606	0.945100	2.643909	1.417650	3.525212	1.890200	4.406515	2.362750	48
14	0.881028	0.473063	1.762056	0.946126	2.648084	1.419189	3.524112	1.892252	4.405140	2.365315	46
16	0.880753	0.473575	1.761506	0.947150	2,642259	1.420725	3.523012	1.894300	4.403765	2.367875	44
18	0.880477	0.474088	1.760954	0.948176	2.641431	1.422264	3.521908	1.896352	4.402385	2.370440	42
20	0.880201	0.474600	1.760402	0.949200	2.640603	1.423800	3.520804	1.898400	4.401005	2.373000	40
22	0.879925	0.475112	1.759850	0.950224	2.639775	1.425336	3.519700	1.900448	4.399625	2.375560	38
24	0.879648	0.475624	1.759296	0.951248	2.638944	1.426872	3.518592	1.902496	4.398240	2.378120	36
26	0.879371	0.476135	1.758742	0.952270	2.638113	1.428405	3.517484	1.904540	4.396855	2.380675	34
28	0.879094	0.476647	1.758188	0.953294	2.637282	1.429941	3.516376	1.906588	4.395470	2.383235	32
30	0.878817	0.477158	1.757634	0.954316	2.636451	1.431474	3.515268	1.908632	4.394085	2.385790	30
32	0.878539	0.477670	1.757078	0.955340	2.635617	1.433010	3.514156	1.910680	4.392695	2.388350	28
34	0.878261	0.478181	1.756522	0.956362	2.634783	1.434543	3.513044	1.912724	4.391305	2.390905	26
36	0.877983	0.478691	1.755966	0.957382	2.633949	1.436073	3.511932	1.914764	4.389915	2.393455	24
38	0.877704	0.479202	1.755408	0.958404	2.633112	1.437606	3.510816	1.916808	4.388520	2.396010	22
40	0.877425	0.479713	1.754850	0.959426	2.632275	1.439139	3.509700	1.918852	4.387125	2.398565	20
42	0.877146	0.480223	1.754292	0.960446	2,631438	1.440669	3.508584	1.920892	4.385730	2.401115	18
44	0.876866	0.480733	1.753732	0.961466	2.630598	1.442199	3.507464	1.922932	4.384330	2.403665	16
46	0.876586	0.481243	1.753172	0.962486	2.629758	1.443729	3.506344	1.924972	4.382930	2.406215	14
48	0.876306	0.481753	1.752612	0.963506	2.628918	1.445259	3.505224	1.927012	4.381530	2.408765	12
50	0.876026	0.482263	1.752052	0.964526	2.628078	1.446789	3.504104	1.929052	4.380130	2.411315	10
52	0.875745	0.482773	1.751490	0.965546	2.627235	1.448319	3.502980	1.931092	4.378725	2.413865	8
54	0.875464	0.483282	1.750928	0.966564	2.626392	1.449846	3.501856	1.933128	4.377320	2.416410	6
56	0.875183	0.483791	1.750366	0.967582	2.625549	1.451373	3.500732	1.935164	4.375915	2.418955	4
58	0.874901	0.484300	1.749802	0.968600	2.624703	1.452900	3.499604	1.937200	4.374605	2.421500	2
60	0.874619	0.484809	1.749238	0.969618	2.623857	1.454427	3.498476	1.939236	4.373095	2.421015	61°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
29°	0.874619	0.484809	1.749238	0.969618	2.623857	1.454427	3.498476	1.939236	4.373095	2.424045	60′
2	0.874337	0.485318	1.748674	0.970636	2.623011	1.455954	3.497348	1.941272	4.371685	2.426590	58
4	0.874056	0.485827	1.748110	0.971654	2.622165	1.457481	3.496220	1.943308	4.370275	2.429135	56
6	0.873772	0.486335	1.747544	0.972670	2.621316	1.459005	3.495088	1.945340	4.368860	2.431675	54
8	0.873489	0.486843	1.746978	0.973686	2.620467	1.460529	3.493956	1.947372	4.367445	2.434215	52
10	0.873205	0.487351	1.746410	0.974702	2.619615	1.462053	3.492820	1.949404	4.366025	2.436755	50
12	0.872922	0.487859	1.745844	0.975718	2.618766	1.463577	3.491688	1.951436	4.364610	2.439295	48
14	0.872638	0.488367	1.745276	0.976734	2.617914	1.465101	3.490552	1.953468	4.363190	2.441835	46
16	0.872353	0.488875	1.744706	0.977750	2.617059	1.466625	3.489412	1.955500	4.361765	2.444375	44
18	0.872069	0.489382	1.744138	0.978764	2.616207	1.468146	3.488276	1.957528	4.360345	2.446910	42
20	0.871784	0.489889	1.743568	0.979778	2.615352	1.469667	3.487136	1.959556	4.358920	2.449445	40
22	0.871499	0.490396	1.742998	0.980792	2.614497	1.471188	3.485996	1.961584	4.357495	2.451980	38
24	0.871213	0.490903	1.742426	0.981806	2.613639	1.472709	3.484852	1.963612	4.356065	2.454515	36
26	0.870928	0.491410	1.741856	0.982820	2.612784	1.474230	3.483712	1.965640	4.354640	2.457050	34
28	0.870642	0.491917	1.741284	0.983834	2.611926	1.475751	3.482568	1.967668	4.353210	2.459585	32
30	0.870355	0.492424	1.740710	0.984846	2.611065	1.477269	3.481420	1.969692	4.351775	2.462115	30
32	0.870069	0.492929	1.740138	0.985858	2.610207	1.478787	3.480276	1.971716	4.350345	2.464645	28
34	0.869782	0.493435	1.739564	0.986870	2.609346	1.480305	3.479128	1.973740	4.348910	2.467175	26
36	0.869494	0.493941	1.738988	0.987882	2.608482	1.481823	3.477976	1.975764	4.347470	2.469705	24
38	0.869207	0.494447	1.738414	0.988894	2.607621	1.483341	3.476828	1.977788	4.346035	2.472235	22
40	0.868919	0.494953	1.737838	0.989906	2.606757	1.484859	3.475676	1.979812	4.344595	2.474765	20
42	0.868631	0.495458	1.737262	0.990916	2.605893	1.486374	3.474524	1.981832	4.343155	2.477290	18
44	0.868343	0.495963	1.736686	0.991926	2.605029	1.487889	3.473372	1.983852	4.341715	2.479815	16
46	0.868054	0.496469	1.736108	0.992938	2.604162	1.489407	3.472216	1.985876	4.340270	2.482345	14
48	0.867765	0.496974	1.735530	0.993948	2.603295	1.490922	3.471060	1.987896	4.338825	2.484870	12
50	0.867476	0.497478	1.734952	0.994956	2.602428	1.492434	3.469904	1.989912	4.337380	2.487390	10
52	0.867186	0.497983	1.734373	0.995966	2.601558	1.493949	3.468744	1.991932	4.335930	2.489915	8
54	0.866896	0.498487	1.733792	0.996974	2.600688	1.495461	3.467584	1.993948	4.334480	2.492435	6
56	0.866606	0.498992	1.733212	0.997984	2.599818	1.496976	3.466424	1.995968	4.333030	2.494960	4
58	0.866316	0.499496	1.732632	0.998992	2.598948	1.498488	3.465264	1.997984	4.331580	2.497480	2
60	0.866025	0.500000	1.732050	1.000000	2.598075	1.500000	3.464100	2.000000	4.330125	2.500000	60°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
30°	0.866025	0.500000	1.732050	1.000000	2.598075	1.500000	3.464100	2.000000	4.330125	2.500000	60′
2′	0.865734	0.500503	1.731468	1.001006	2.597202	1.501509	3.462936	2.002012	4.328670	2.502515	58
4	0.865443	0.501007	1.730886	1.002014	2.596329	1.503021	3.461772	2.004028	4.327215	2.505035	56
6	0.865151	0.501510	1.730302	1.003020	2.595453	1.504530	3.460604	2.006040	4.325755	2.507550	54
8	0.864859	0.502014	1.729718	1.004028	2.594577	1.506042	3.459436	2.008056	4.324295	2.510070	52
10	0.864567	0.502517	1.729134	1.005034	2.593701	1.507551	3.458268	2.010068	4.322835	2.512585	50
12	0.864274	0.503019	1.728548	1.006038	2.592822	1.509057	3.457096	2.012076	4.321370	2.515095	48
14	0.863982	0.503522	1.727964	1.007044	2.591946	1.510566	3.455928	2.014088	4.319910	2.517610	46
16	0.863688	0.504025	1.727376	1.008050	2.591064	1.512075	3.454752	2.016100	4.318440	2.520125	44
18	0.863395	0.504527	1.726790	1.009054	2.590185	1.513581	3.453580	2.018108	4.316975	2.522635	42
20	0.863101	0.505029	1.726202	1.010058	2.589303	1.515087	3.452404	2.020116	4.315505	2.525145	40
22	0.862807	0.505531	1.725614	1.011062	2.588421	1.516593	3.451228	2.022124	4.314035	2.527655	38
24	0.862513	0.506033	1.725026	1.012066	2.587539	1.518099	3.450052	2.024132	4.312565	2.530165	36
26	0.862219	0.506535	1.724438	1.013070	2.586657	1.519605	3.448876	2.026140	4.311095	2.532675	34
28	0.861924	0.507037	1.723848	1.014074	2.585772	1.521111	3.447696	2.028148	4.309620	2.535185	32
30	0.861629	0.507538	1.723258	1.015076	2.584887	1.522614	3.446516	2.030152	4.308145	2.537690	30
32	0.861333	0.508039	1.722666	1.016078	2.583999	1.524117	3.445332	2.032156	4.306665	2.540195	28
34	0.861038	0.508540	1.722076	1.017080	2.583114	1.525620	3.444152	2.034160	4.305190	2.542700	26
36	0.860742	0.509041	1.721484	1.018082	2.582226	1.527123	3.442968	2.036164	4.303710	2.545205	24
38	0.860445	0.509542	1.720890	1.019084	2.581335	1.528626	3.441780	2.038168	4.302225	2.547710	22
40	0.860149	0.510042	1.720298	1.020084	2.580447	1.530126	3.440596	2.040168	4.300745	2.550210	20
42	0.859852	0.510542	1.719704	1.021084	2.579556	1.531626	3.439408	2.042168	4.299260	2.552710	18
44	0.859555	0.511043	1.719110	1.022086	2.578665	1.533129	3.438220	2.044172	4.297775	2.555215	16
46	0.859257	0.511543	1.718514	1.023086	2.577771	1.534629	3.437028	2.046172	4.296285	2.557715	14
48	0.858959	0.512042	1.717918	1.024084	2.576877	1.536126	3.435836	2.048168	4.294795	2.560210	12
50	0.858661	0.512542	1.717322	1.025084	2.575983	1.537626	3.434644	2.050168	4.293305	2.562710	10
52	0.858363	0.513042	1.716726	1.026084	2.575089	1.539126	3.433452	2.052168	4.291815	2.565210	8
54	0.858064	0.513541	1.716128	1.027082	2.574192	1.540623	3.432256	2.054164	4.290320	2.567705	6
56	0.857766	0.514040	1.715532	1.028080	2.573298	1.542120	3.431064	2.056160	4.288830	2.570200	4
58	0.857466	0.514539	1.714932	1.029078	2.572398	1.543617	3.429864	2.058156	4.287330	2.572695	2
60	0.857167	0.515038	1.714334	1.030076	2.571501	1.545114	3.428668	2.060152	4.285835	2.575190	59°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
31°	0.857167	0.515038	1.714334	1.030076	2.571501	1.545114	3.428668	2.060152	4.285835	2.575190	60′
2	0.856867	0.515536	1.713734	1.031072	2.570601	1.546608	3.427468	2.062144	4.284335	2.577680	58
4	0.856567	0.516035	1.713134	1.032070	2.569701	1.548105	3.426268	2.064140	4.282835	2.580175	56
6	0.856267	0.516533	1.712534	1.033066	2.568801	1.549599	3.425068	2.066132	4.281335	2.582665	54
8	0.855966	0.517031	1.711932	1.034062	2.567898	1.551093	3.423864	2.068124	4.279830	2.585155	52
10	0.855665	0.517529	1.711330	1.035058	2.566995	1.552587	3.422660	2.070116	4.278325	2.587645	50
12	0.855364	0.518027	1.710728	1.036054	2.566092	1.554081	3.421456	2.072108	4.276820	2.590135	48
14	0.855062	0.518524	1.710124	1.037048	2.565186	1.555572	3.420248	2.074096	4.275310	2.592620	46
16	0.854760	0.519021	1.709520	1.038042	2.564280	1.557063	3.419040	2.076084	4.273800	2.595105	44
18	0.854458	0.519519	1.708916	1.039038	2.563374	1.558557	3.417832	2.078076	4.272290	2.597595	42
20	0.854156	0.520016	1.708312	1.040032	2.562468	1.560048	3.416624	2.080064	4.270780	2.600080	40
22	0.853853	0.520513	1.707706	1.041026	2.561559	1.561539	3.415412	2.082052	4.269265	2.602565	38
24	0.853550	0.521009	1.707100	1.042018	2.560650	1.563027	3.414200	2.084036	4.267750	2.605045	36
26	0.853247	0.521506	1.706494	1.043012	2.559741	1.564518	3.412988	2.086024	4.266235	2.607530	34
28	0.852944	0.522002	1.705888	1.044004	2.558832	1.566006	3.411776	2.088008	4.264720	2.610010	32
30	0.852640	0.522498	1.705280	1.044996	2.557920	1.567494	3.410560	2.089992	4.263200	2.612490	30
32	0.852336	0.522994	1.704672	1.045988	2.557008	1.568982	3.409344	2.091976	4.261680	2.614970	28
34	0.852031	0.523490	1.704062	1.046980	2.556093	1.570470	3.408124	2.093960	4.260155	2.617450	26
36	0.851726	0.523985	1.703452	1.047970	2.555178	1.571955	3.406904	2.095940	4.258630	2.619925	24
38	0.851421	0.524481	1.702842	1.048962	2.554263	1.573443	3.405684	2.097924	4.257105	2.622405	22
40	0.851116	0.524976	1.702232	1.049952	2.553348	1.574928	3.404464	2.099904	4.255580	2.624880	20
42	0.850811	0.525471	1.701622	1.050942	2.552433	1.576413	3.403244	2.101884	4.254055	2.627355	18
44	0.850505	0.525966	1.701010	1.051932	2.551515	1.577898	3.402020	2.103864	4.252525	2.629830	16
46	0.850199	0.526461	1.700398	1.052922	2.550597	1.579383	3.400796	2.105844	4.250995	2.632305	14
48	0.849892	0.526955	1.699784	1.053910	2.549676	1.580865	3.399568	2.107820	4.249460	2.634775	12
50	0.849586	0.527450	1.699172	1.054900	2.548758	1.582350	3.398344	2.109800	4.247930	2.637250	10
52	0.849279	0.527944	1.698558	1.055888	2.547837	1.583832	3.397116	2.111776	4.246395	2.639720	8
54	0.848971	0.528438	1.697942	1.056876	2.546913	1.585314	3.395884	2.113752	4.244855	2.642190	6
56	0.848664	0.528932	1.697328	1.057864	2.545992	1.586796	3.394656	2.115728	4.243320	2.644660	4
58	0.848356	0.529425	1.696712	1.058840	2.545068	1.588275	3.393424	2.117680	4.241780	2.647125	2
60	0.848048	0.529919	1.696096	1.059838	2.544144	1.589757	3.392192	2.119676	4.240240	2.649595	58°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000. Distance from Planes of Meridian, or East or West Distance.	Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000. Distance from Planes of Latitude, or North or South Distance.	Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000. Distance from Planes of Meridian, or East or West Distance.	
32°	0.848048	0.529919	1.696096	1.059838	2.544144	1.589757	3.392192	2.119676	4.240240	2.649595	60'
2	0.847739	0.530412	1.695478	1.060824	2.543217	1.591236	3.390956	2.121648	4.238695	2.652060	58
4	0.847430	0.530905	1.694860	1.061810	2.542290	1.592715	3.389720	2.123620	4.237150	2.654525	56
6	0.847121	0.531398	1.694242	1.062796	2.541363	1.594194	3.388484	2.125592	4.235605	2.656990	54
8	0.846812	0.531891	1.693624	1.063782	2.540436	1.595673	3.387248	2.127564	4.234060	2.659455	52
10	0.846503	0.532383	1.693006	1.064766	2.539509	1.597149	3.386012	2.129532	4.232515	2.661915	50
12	0.846193	0.532876	1.692386	1.065752	2.538579	1.598628	3.384772	2.131504	4.230965	2.664380	48
14	0.845883	0.533368	1.691766	1.066736	2.537649	1.600104	3.383532	2.133472	4.229415	2.666840	46
16	0.845572	0.533860	1.691144	1.067720	2.536716	1.601580	3.382288	2.135440	4.227860	2.669300	44
18	0.845261	0.534352	1.690522	1.068704	2.535783	1.603056	3.381044	2.137408	4.226305	2.671760	42
20	0.844950	0.534844	1.689900	1.069688	2.534850	1.604532	3.379800	2.139376	4.224750	2.674220	40
22	0.844639	0.535335	1.689278	1.070670	2.533917	1.606005	3.378556	2.141340	4.223195	2.676675	38
24	0.844327	0.535826	1.688654	1.071652	2.532981	1.607478	3.377308	2.143304	4.221635	2.679130	36
26	0.844016	0.536317	1.688032	1.072634	2.532048	1.608951	3.376064	2.145268	4.220080	2.681585	34
28	0.843703	0.536808	1.687406	1.073616	2.531109	1.610424	3.374812	2.147232	4.218515	2.684040	32
30	0.843391	0.537299	1.686782	1.074598	2.530173	1.611897	3.373564	2.149196	4.216955	2.686495	30
32	0.843078	0.537790	1.686156	1.075580	2.529234	1.613370	3.372312	2.151160	4.215390	2.688950	28
34	0.842765	0.538280	1.685530	1.076560	2.528295	1.614840	3.371060	2.153120	4.213825	2.691400	26
36	0.842452	0.538770	1.684904	1.077540	2.527356	1.616310	3.369808	2.155080	4.212260	2.693850	24
38	0.842138	0.539260	1.684276	1.078520	2.526414	1.617780	3.368552	2.157040	4.210690	2.696300	22
40	0.841824	0.539750	1.683648	1.079500	2.525472	1.619250	3.367296	2.159000	4.209120	2.698750	20
42	0.841510	0.540240	1.683020	1.080480	2.524530	1.620720	3.366040	2.160960	4.207550	2.701200	18
44	0.841196	0.540729	1.682392	1.081458	2.523588	1.622187	3.364784	2.162916	4.205980	2.703645	16
46	0.840881	0.541219	1.681762	1.082438	2.522643	1.623657	3.363524	2.164876	4.204405	2.706095	14
48	0.840566	0.541708	1.681132	1.083416	2.521698	1.625124	3.362264	2.166832	4.202830	2.708540	12
50	0.840251	0.542197	1.680502	1.084394	2.520753	1.626591	3.361004	2.168788	4.201255	2.710985	10
52	0.839935	0.542685	1.679870	1.085370	2.519805	1.628055	3.359740	2.170740	4.199675	2.713425	8
54	0.839819	0.543174	1.679638	1.086348	2.519457	1.629522	3.359276	2.172696	4.199095	2.715870	6
56	0.839303	0.543662	1.678606	1.087324	2.517909	1.630986	3.357212	2.174648	4.196515	2.718310	4
58	0.838987	0.544151	1.677974	1.088302	2.516961	1.632453	3.355948	2.176604	4.194935	2.720755	2
60	0.838670	0.544639	1.677340	1.089278	2.516010	1.633917	3.354680	2.178556	4.193350	2.723195	57°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
33°	0.838670	0.544639	1.677340	1.089278	2.516010	1.633917	3.354680	2.178556	4.193350	2.723195	60'
2	0.838353	0.545126	1.676706	1.090252	2.515059	1.635378	3.353412	2.180504	4.191765	2.725630	58
4	0.838036	0.545614	1.676072	1.091228	2.514108	1.636842	3.352144	2.182456	4.190180	2.728070	56
6	0.837718	0.546102	1.675436	1.092204	2.513154	1.638306	3.350872	2.184408	4.188590	2.730510	54
8	0.837400	0.546589	1.674800	1.093178	2.512200	1.639767	3.349600	2.186356	4.187000	2.732945	52
10	0.837082	0.547076	1.674164	1.094152	2.511246	1.641228	3.348328	2.188304	4.185410	2.735380	50
12	0.836764	0.547563	1.673528	1.095126	2.510292	1.642689	3.347056	2.190252	4.183820	2.737815	48
14	0.836445	0.548049	1.672890	1.096098	2.509335	1.644147	3.345780	2.192196	4.182225	2.740245	46
16	0.836126	0.548536	1.672252	1.097072	2.508378	1.645608	3.344504	2.194144	4.180630	2.742680	44
18	0.835807	0.549022	1.671614	1.098044	2.507421	1.647066	3.343228	2.196088	4.179035	2.745110	42
20	0.835487	0.549509	1.670974	1.099018	2.506461	1.648527	3.341948	2.198036	4.177435	2.747545	40
22	0.835168	0.549995	1.670336	1.099990	2.505504	1.649985	3.340672	2.199980	4.175840	2.749975	38
24	0.834847	0.550480	1.669694	1.100960	2.504541	1.651440	3.339388	2.201920	4.174235	2.752400	36
26	0.834527	0.550966	1.669054	1.101932	2.503581	1.652898	3.338108	2.203864	4.172635	2.754830	34
28	0.834206	0.551451	1.668412	1.102902	2.502618	1.654353	3.336824	2.205804	4.171030	2.757255	32
30	0.833885	0.551937	1.667770	1.103874	2.501655	1.655811	3.335540	2.207748	4.169425	2.759685	30
32	0.833564	0.552422	1.667128	1.104844	2.500692	1.657266	3.334256	2.209688	4.167820	2.762110	28
34	0.833243	0.552906	1.666486	1.105812	2.499729	1.658718	3.832975	2.211624	4.166215	2.764530	26
36	0.832921	0.553391	1.665842	1.106782	2.498763	1.660173	3.331694	2.213564	4.164605	2.766955	24
38	0.832599	0.553876	1.665198	1.107752	2.497797	1.661628	3.330396	2.215504	4.162995	2.769380	22
40	0.832376	0.554360	1.664752	1.108720	2.497128	1.663080	3.329504	2.217440	4.161880	2.771800	20
42	0.831954	0.554844	1.663908	1.109688	2.495862	1.664532	3.327816	2.219376	4.159770	2.774220	18
44	0.831631	0.555323	1.663262	1.110656	2.494893	1.665984	3.326524	2.221312	4.158155	2.776640	16
46	0.831308	0.555812	1.662616	1.111624	2.493924	1.667436	3.325232	2.223248	4.156540	2.779060	14
48	0.830984	0.556295	1.661968	1.112590	2.492952	1.668885	3.323936	2.225180	4.154920	2.781475	12
50	0.830660	0.556779	1.661320	1.113558	2.491980	1.670337	3.322640	2.227116	4.153300	2.783895	10
52	0.830336	0.557262	1.660672	1.114524	2.491008	1.671786	3.321344	2.229048	4.151680	2.786310	8
54	0.830012	0.557745	1.660024	1.115490	2.490036	1.673235	3.320048	2.230980	4.150060	2.788725	6
56	0.829687	0.558227	1.659374	1.116454	2.489061	1.674681	3.318748	2.232908	4.148435	2.791135	4
58	0.829362	0.558710	1.658724	1.117420	2.488086	1.676130	3.317448	2.234840	4.146810	2.793550	2
60	0.829037	0.559192	1.658074	1.118384	2.487111	1.677576	3.316148	2.236768	4.145185	2.795960	56°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse. 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		•
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
34°	0.829037	0.559192	1.658074	1.118384	2.487111	1.677576	3.316148	2.236768	4.145185	2.795960	60′
2′	0.828712	0.559675	1.657424	1.119350	2.486136	1.679025	3.314848	2.238700	4.143560	2.798375	58
4	0.828386	0.560157	1.656772	1.120314	2.485158	1.680471	3.313544	2.240628	4.141930	2.800785	56
6	0.828060	0.560639	1.656120	1.121278	2.484180	1.681917	3.312240	2.242556	4.140300	2.803195	54
8	0.827734	0.561120	1.655468	1.122240	2.483202	1.683360	3.310936	2.244480	4.138670	2.805600	52
10	0.827407	0.561602	1.654814	1.123204	2.482221	1.684806	3.309628	2.246408	4.137035	2.808010	50
12	0.827080	0.562083	1.654160	1.124166	2.481240	1.686249	3.308320	2.248332	4.135400	2.810415	48
14	0.826753	0.562564	1.653506	1.125128	2.480259	1.687692	3.307012	2.250256	4.133765	2.812820	46
16	0.826426	0.563045	1.652852	1.126090	2.479278	1.689135	3.305704	2.252180	4.132130	2.815225	44
18	0.826098	0.563526	1.652196	1.127052	2.478294	1.690578	3.304392	2.254104	4.130490	2.817630	42
20	0.825770	0.564006	1.651540	1.128012	2 477310	1.692018	3.303080	2.256024	4.128850	2.820030	40
22	0.825442	0.564486	1.650884	1.128972	2.476326	1.693458	3.301768	2.257944	4.127210	2.822430	38
24	0.825113	0.564967	1.650226	1.129934	2.475339	1.694901	3.300452	2.259868	4.125565	2.824835	36
26	0.824784	0.565446	1.649568	1.130892	2.474352	1.696338	3.299136	2.261784	4.123920	2.827230	34
28	0.824455	0.565926	1.648910	1.131852	2.473365	1.697778	3.297820	2.263704	4.122275	2.829630	32
30	0.824126	0.566406	1.648252	1.132812	2.472378	1.699218	3.296504	2.265624	4.120630	2.832030	30
32	0.823796	0.566885	1.647592	1.133770	2.471388	1.700655	3.295184	2.267540	4.118980	2.834425	28
34	0.823466	0.567364	1.646932	1.134728	2.470398	1.702092	3.293864	2.269456	4.117330	2.836820	26
36	0.823136	0.567843	1.646272	1.135686	2.469408	1.703529	3.292544	2.271372	4.115680	2.839215	24
38	0.822805	0.568322	1.645610	1.136644	2.468415	1.704966	3.291220	2.273288	4.114025	2.841610	22
40	0.822475	0.568801	1.644950	1.137602	2.467425	1.706403	3.289900	2.275204	4.112375	2.844005	20
42	0.822144	0.569279	1.644288	1.138558	2.466432	1.707837	3.288576	2.277116	4.110720	2.846395	18
44	0.821812	0.569757	1.643624	1.139514	2.465436	1.709271	3.287248	2.279028	4.109060	2.848785	16
46	0.821481	0.570235	1.642962	1.140470	2.464443	1.710705	3.285924	2.280940	4.107405	2.851175	14
48	0.821149	0.570713	1.642298	1.141426	2.463447	1.712139	3.284596	2.282852	4.105745	2.853565	12
50	0.820817	0.571191	1.641634	1.142382	2.462451	1.713573	3.283268	2.284764	4.104085	2.855955	10
52	0.820484	0.571668	1.640968	1.143336	2.461452	1.715004	3.281936	2.286672	4.102420	2.858340	8
54	0.820151	0.572145	1.640302	1.144290	2.460453	1.716435	3.280604	2.288580	4.100755	2.860725	6
56	0.819818	0.572622	1.639636	1.145244	2.459454	1.717866	3.279272	2.290488	4.099090	2.863110	4
58	0.819485	0.573099	1.638970	1.146198	2.458455	1.719297	3.277940	2.292396	4.097425	2.865495	2
60	0.819152	0.573576	1.638304	1.147152	2.457456	1.720728	3.276608	2.294304	4.095760	2.867880	55°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		•

Degrees and Minutes	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
35°	0.819152	0.573576	1.638304	1.147152	2.457456	1.720728	3.276608	2.294304	4.095760	2.867880	60′
2	0.818818	0.574052	1.637636	1.148104	2.456454	1.722156	3.275272	2.296208	4.094090	2.870260	58
4	0.818484	0.574529	1.636968	1.149058	2.455452	1.723587	3.273936	2.298116	4.092420	2.872645	56
6	0.818149	0.575005	1.636298	1.150010	2.454447	1.725015	3.272596	2.300020	4.090745	2.875025	54
8	0.817815	0.575481	1.635630	1.150962	2.453445	1.726443	3.271260	2.301964	4.089075	2.877405	52
10	0.817480	0.575956	1.634960	1.151912	2.452440	1.727868	3.269920	2.303824	4.087400	2.879780	50
12	0.817144	0.576432	1.634288	1.152864	2.451432	1.729296	3.268576	2.305728	4.085720	2.882160	48
14	0.816809	0.576907	1.633618	1.153814	2.450427	1.730721	3.267236	2.307628	4.084045	2.884535	46
16	0.816473	0.577382	1.632946	1.154764	2.449419	1.732146	3.265892	2.309523	4.082365	2.886910	44
18	0.816137	0.577857	1.632274	1.155714	2.448411	1.733571	3.264548	2.311428	4.080685	2.889285	42
20	0.815801	0.578332	1.631602	1.156664	2.447403	1.734996	3.263204	2.313328	4.079005	2.891660	40
22	0.815464	0.578806	1.630928	1.157612	2.446392	1.736418	3.261856	2.315224	4.077320	2.894030	38
24	0.815127	0.579281	1.630254	1.158562	2.445381	1.737843	3.260508	2.317124	4.075635	2.896405	36
26	0.814790	0.579755	1.629580	1.159510	2.444370	1.739265	3.259160	2.319020	4.073950	2.898775	34
28	0.814453	0.580229	1.628906	1.160458	2.443359	1.740687	3.257812	2.320916	4.072265	2.901145	32
30	0.814116	0.580703	1.628230	1.161406	2.442345	1.742109	3.256460	2.322812	4.070575	2.903515	30
32	0.813777	0.581176	1.627554	1.162352	2.441331	1.743528	3.255108	2.324704	4.068885	2.905880	28
34	0.813439	0.581649	1.626878	1.163298	2.440317	1.744947	3.253756	2.326596	4.067195	2.908245	26
36	0.813100	0.582123	1.626200	1.164246	2.439300	1.746369	3.252400	2.328492	4.065500	2.910615	24
38	0.812762	0.582595	1.625524	1.165190	2.438286	1.747785	3.251048	2.330380	4.063810	2.912975	22
40	0.812422	0.583068	1.624844	1.166136	2.437266	1.749204	3.249688	2.332272	4.062110	2.915340	20
42	0.812083	0.583541	1.624166	1.167082	2.436249	1.750623	3.248332	2.334164	4.060415	2.917705	18
44	0.811743	0.584013	1.623486	1.168026	2.435229	1.752039	3.246972	2.336052	4.058715	2.920065	16
46	0.811404	0.584485	1.622808	1.168970	2.434212	1.753455	3.245616	2.337940	4.057020	2.922425	14
48	0.811063	0.584957	1.622126	1.169914	2.433189	1.754871	3.244252	2.339828	4.055315	2.924785	12
50	0.810723	0.585429	1.621446	1.170858	2.432169	1.756287	3.242892	2.341716	4.053615	2.927145	10
52	0.810382	0.585901	1.620764	1.171802	2.431146	1.757703	3.241528	2.343604	4.051910	2.929505	8
54	0.810041	0.586372	1.620082	1.172744	2.430123	1.759116	3.240164	2.345488	4.050205	2.931860	6
56	0.809700	0.586843	1.619400	1.173686	2.429100	1.760529	3.238800	2.347372	4.048500	2.934215	4
58	0.809358	0.587314	1.618716	1.174628	2.428074	1.761942	3.237432	2.349256	4.046790	2.936570	2
60	0.809017	0.587785	1.618034	1.175570	2.427051	1.763355	3.236068	2.351140	4.045085	2.938925	54°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
36°	0.809017	0.587785	1.618034	1.175570	2.427051	1.763355	3.236068	2.351140	4.045085	2.938925	60′
2′	0.808674	0.588255	1.617348	1.176510	2.426022	1.764765	3.234696	2.353020	4.043870	2.941275	58
4	0.808332	0.588726	1.616664	1.177452	2.424996	1.766178	3.233328	2.354904	4.041660	2.943630	56
6	0.807989	0.589196	1.615978	1.178392	2.423967	1.767588	3.231956	2.356784	4.039945	2.945980	54
8	0.807647	0.589666	1.615294	1.179332	2.422941	1.768998	3.230588	2.358664	4.038235	2.948330	52
10	0.807303	0.590136	1.614606	1.180272	2.421909	1.770408	3.229212	2.360544	4.036515	2.950680	50
12	0.806960	0.590605	1.613920	1.181210	2.420880	1.771815	3.227840	2.362420	4.034800	2.953025	48
14	0.806616	0.591075	1.613232	1.182150	2.419848	1.773225	3.226464	2.364300	4.033080	2.955375	46
16	0.806272	0.591544	1.612544	1.183088	2.418816	1.774632	3.225088	2.366176	4.031360	2.957720	44
18	0.805928	0.592013	1.611856	1.184026	2.417784	1.776039	3.223712	2.368052	4.029640	2.960065	42
20	0.805583	0.592481	1.611166	1.184962	2.416749	1.777443	3.222332	2.369924	4.027915	2.962405	40
22	0.805238	0.592950	1.610476	1.185900	2.415714	1.778850	3.220952	2.371800	4.026190	2.964750	38
24	0.804893	0.593418	1.609786	1.186836	2.414679	1.780254	3.219572	2.373672	4.024465	2.967090	36
26	0.804548	0.593887	1.609096	1.187774	2.413644	1.781661	3.218192	2.375548	4.022740	2.969435	34
28	0.804202	0.594355	1.608404	1.188710	2.412606	1.783065	3.216808	2.377420	4.021010	2.971775	32
30	0.803856	0.594822	1.607712	1.189644	2.411568	1.784466	3.215424	2.379288	4.019280	2.974110	30
32	0.803510	0.595290	1.607020	1.190580	2.410530	1.785870	3.214040	2.381160	4.017550	2.976450	28
34	0.803164	0.595757	1.606328	1.191514	2.409492	1.787371	3.212656	2.383028	4.015820	2.978785	26
36	0.802817	0.596224	1.605634	1.192448	2.408451	1.788672	3.211268	2.384896	4.014085	2.981120	24
38	0.802470	0.596691	1.604940	1.193382	2.407410	1.790073	3.209880	2.386764	4.012350	2.983455	22
40	0.802123	0.597158	1.604246	1.194316	2.406369	1.791474	3.208492	2.388632	4.010615	2.985790	20
42	0.801775	0.597625	1.603550	1.195250	2.405325	1.792875	3.207100	2.390500	4.008875	2.988125	18
44	0.801427	0.598091	1.602854	1.196182	2.404281	1.794273	3.205708	2.392364	4.007135	2.990455	16
46	0.801079	0.598557	1.602158	1.197114	2.403237	1.795671	3.204316	2.394228	4.005395	2.992785	14
48	0.800731	0.599023	1.601462	1.198046	2.402193	1.797069	3.202924	2.396092	4.003655	2.995115	12
50	0.800382	0.599489	1.600764	1.198978	2.401146	1.798467	3.201528	2.397956	4.001910	2.997445	10
52	0.800033	0.599954	1.600066	1.199908	2.400099	1.799862	3.200132	2.399816	4.000165	2.999770	8
54	0.799684	0.600420	1.599368	1.200840	2.399052	1.801260	3.198736	2.401680	3.998420	3.002100	6
56	0.799335	0.600885	1.598670	1.201770	2.398005	1.802655	3.197340	2.403540	3.996675	3.004425	4
58	0.798985	0.601350	1.597970	1.202700	2.396955	1.804050	3.195940	2.405400	3.994925	3.006750	2
60	0.798635	0.601815	1.597270	1.203630	2.395905	1.805445	3.194540	2.407260	3.993175	3.009075	53°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
37°	0.798635	0.601815	1.597270	1.203630	2.395905	1.805445	3.194540	2.407260	3.993175	3.009075	60′
2	0.798285	0.602279	1.596570	1.204558	2.394855	1.806837	3.193140	2.409116	3.991425	3.001395	58
4	0.797934	0.602743	1.595868	1.205486	2.393802	1.808229	3.191736	2.410972	3.989670	3.013715	56
6	0.797583	0.603208	1.595166	1.206416	2.392749	1.809624	3.190332	2.412832	3.987915	3.016040	54
8	0.797232	0.603671	1.594464	1.207342	2.391696	1.811013	3.188928	2.414684	3.986160	3.018355	52
10	0.796881	0.604135	1.593762	1.208270	2.390643	1.812405	3.187524	2.416540	3.984405	3.020675	50
12	0.796529	0.604599	1.593058	1.209198	2.389587	1.813797	3.186116	2.418396	3.982645	3.022995	48
14	0.796178	0.685062	1.592356	1.210124	2.388534	1.815186	3.184712	2.420248	3.980890	3.025310	46
16	0.795825	0.605525	1.591650	1.211050	2.387475	1.816575	3.183300	2.422100	3.979125	3.027625	44
18	0.795473	0.605988	1.590946	1.211976	2.386419	1.817964	3.181892	2.423952	3.977365	3.029940	42
20	0.795121	0.606451	1.590242	1.212902	2.385363	1.819353	3.180484	2.425804	3.975605	3.032255	40
22	0.794767	0.606913	1.589534	1.213826	2.384301	1.820739	3.179068	2.427652	3.973835	3.034565	38
24	0.794414	0.607375	1.588828	1.214750	2.383242	1.822125	3.177656	2.429500	3.972070	3.036875	36
26	0.794061	0.607837	1.588122	1.215674	2.382183	1.823511	3.176244	2.431348	3.970305	3.039185	34
28	0.793707	0.608299	1.587414	1.216598	2.381121	1.824897	3.174828	2.433196	3.968535	3.041495	32
30	0.793353	0.608761	1.586706	1.217522	2.380059	1.826283	3.173412	2.435044	3.966765	3.043805	30
32	0.792999	0.609222	1.585998	1.218444	2.378997	1.827666	3.171996	2.436888	3.964995	3.046110	28
34	0.792644	0.609684	1.585288	1.219368	2.377932	1.829052	3.170576	2.438736	3.963220	3.048420	26
36	0.792289	0.610145	1.584578	1.220290	2.376867	1.830435	3.169156	2.440580	3.961445	3.050725	24
38	0.791934	0.610606	1.583868	1.221212	2.375802	1.831818	3.167736	2.442424	3.959670	3.053030	22
40	0.791579	0.611066	1.583158	1.222132	2.374737	1.833198	3.166316	2.444264	3.957895	3.055330	20
42	0.791223	0.611527	1.582446	1.223054	2.373669	1.834581	3.164892	2.446108	3.956115	3.057635	18
44	0.790867	0.611987	1.581734	1.223974	2.372601	1.835961	3.163468	2.447948	3.954335	3.059935	16
46	0.790511	0.612447	1.581022	1.224894	2.371533	1.837341	3.162044	2.449788	3.952555	3.062235	14
48	0.790155	0.612907	1.580310	1.225814	2.370465	1.838721	3.160620	2.451628	3.950775	3.064535	12
50	0.789798	0.613366	1.579596	1.226732	2.369394	1.840098	3.159192	2.453464	3.948990	3.066830	10
52	0.789441	0.613826	1.578882	1.227652	2.368323	1.841478	3.157764	2.455304	3.947205	3.069130	8
54	0.789084	0.614285	1.578168	1.228570	2.367252	1.842855	3.156336	2.457140	3.945420	3.071425	6
56	0.788726	0.614744	1.577452	1.229488	2.366178	1.844232	3.154904	2.458976	3.943630	3.073720	4
58	0.788368	0.615202	1.576736	1.230404	2.365104	1.845606	3.153472	2.460808	3.941840	3.076010	2
60	0.788010	0.615661	1.576020	1.231322	2.364030	1.846983	3.152040	2.462644	3.940050	3.078305	52°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
38°	0.788010	0.615661	1.576020	1.231322	2.364030	1.846983	3.152040	2.462644	3.940050	3.078305	60′
2	0.787652	0.616119	1.575304	1.232238	2.363956	1.848357	3.150608	2.464476	3.938260	3.080595	58
4	0.787293	0.616578	1.574586	1.233156	2.361879	1.849734	3.149172	2.466312	3.936465	3.082890	56
6	0.786935	0.617035	1.573870	1.234070	2.360805	1.851105	3.147740	2.468140	3.934675	3.085175	54
8	0.786575	0.617493	1.573150	1.234986	2.359725	1.852479	3.146300	2.469972	3.932875	3.087465	52
10	0.786216	0.617951	1.572432	1.235902	2.358648	1.853853	3.144864	2.471804	3.931080	3.089755	50
12	0.785856	0.618408	1.571712	1.236816	2.357568	1.855224	3.143424	2.473632	3.929280	3.092040	48
14	0.785497	0.618865	1.570994	1.237730	2.356491	1.856595	3.141988	2.475460	3.927485	3.094325	46
16	0.785136	0.619322	1.570272	1.238644	2.355408	1.857966	3.140544	2.477288	3.925680	3.096610	44
18	0.784776	0.619779	1.569552	1.239558	2.354328	1.859337	3.139104	2.479116	3.923880	3.098895	42
20	0.784415	0.620235	1.568830	1.240470	2.353245	1.860705	3.137660	2.480940	3.922075	3.101175	40
22	0.784054	0.620691	1.568108	1.241382	2.352162	1.862073	3.136216	2.482764	3.920270	3.103455	38
24	0.783693	0.621147	1.567386	1.242294	2.351079	1.863441	3.134772	2.484588	3.918465	3.105735	36
26	0.783332	0.621603	1.566664	1.243206	2.349996	1.864809	3.133328	2.486412	3.916660	3.108015	34
28	0.782970	0.622059	1.565940	1.244118	2.348910	1.866177	3.131880	2.488236	3.914850	3.110295	32
30	0.782608	0.622514	1.565216	1.245028	2.347824	1.867542	3.130432	2.490056	3.913040	3.112570	30
32	0.782248	0.622969	1.564496	1.245938	2.346744	1.868907	3.128992	2.491876	3.911240	3.114845	28
34	0.781883	0.623424	1.563766	1.246848	2.345649	1.870272	3.127532	2.493696	3.909415	3.117120	26
36	0.781520	0.623879	1.563040	1.247758	2.344560	1.871637	3.126080	2.495516	3.907600	3.119395	24
38	0.781157	0.624334	1.562314	1.248668	2.343471	1.873002	3.124628	2.497336	3.905785	3.121670	22
40	0.780794	0.624788	1.561588	1.249576	2.342382	1.874364	3.123176	2.499152	3.903970	3.123940	20
42	0.780430	0.625242	1.560860	1.250484	2.341290	1.875726	3.121720	2.500968	3.902150	3.126210	18
44	0.780066	0.625696	1.560132	1.251392	2.340198	1.877088	3.120264	2.502784	3.900330	3.128480	16
46	0.779702	0.626150	1.559404	1.252300	2.339106	1.878450	3.118808	2.504600	3.898510	3.130750	14
48	0.779338	0.626603	1.558676	1.253206	2.338014	1.879809	3.117352	2.506412	3.896690	3.133015	12
50	0.778973	0.627057	1.557946	1.254114	2.336919	1.881171	3.115892	2.508228	3.894865	3.135285	10
52	0.778608	0.627510	1.557216	1.255020	2.335824	1.882530	3.114432	2.510040	3.893040	3.137550	8
54	0.778243	0.627963	1.556486	1.255926	2.334729	1.883889	3.112972	2.511852	3.891215	3.139815	6
56	0.777877	0.628415	1.555754	1.256830	2.333631	1.885245	3.111508	2.513660	3.889385	3.142075	4
58	0.777512	0.628868	1.555024	1.257736	2.332536	1.886604	3.110048	2.515472	3.887560	3.144340	2
60	0.777146	0.629320	1.554292	1.258640	2.331438	1.887960	3.108584	2.517280	3.885730	3.146600	51°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
39°	0.777146	0.629320	1.554292	1.258640	2.331438	1.887960	3.108584	2.517280	3.885730	3.146600	60′
2′	0.776779	0.629772	1.553558	1.259544	2.330337	1.889316	3.107116	2.519088	3.883895	3.148860	58
4	0.776413	0.630224	1.552826	1.260448	2.329239	1.890672	3.105652	2.520896	3.882065	3.151120	56
6	0.776046	0.630675	1.552092	1.261350	2.328138	1.892025	3.104184	2.522700	3.880230	3.153375	54
8	0.775679	0.631127	1.551358	1.262254	2.327037	1.893381	3.102716	2.524508	3.878395	3.155635	52
10	0.775312	0.631578	1.550624	1.263156	2.325936	1.894734	3.101248	2.526312	3.876560	3.157890	50
12	0.774944	0.632029	1.549888	1.264058	2.324832	1.896087	3.099776	2.528116	3.874720	3.160145	48
14	0.774576	0.632480	1.549152	1.264960	2.323728	1.897440	3.098304	2.529920	3.872880	3.162400	46
16	0.774208	0.632930	1.548416	1.265860	2.322624	1.898790	3.096832	2.531720	3.871040	3.164650	44
18	0.773840	0.633380	1.547680	1.266760	2.321520	1.900140	3.095360	2.533520	3.869200	3.166900	42
20	0.773471	0.633831	1.546942	1.267662	2.320413	1.901493	3.093884	2.535324	3.867355	3.169155	40
22	0.773102	0.634280	1.546204	1.268560	2.319306	1.902840	3.092408	2.537120	3.865510	3.171400	38
24	0.772733	0.634730	1.545466	1.269460	2.318199	1.904190	3.090932	2.538920	3.863665	3.173650	36
26	0.772364	0.635180	1.544728	1.270360	2.317092	1.905540	3.089456	2.540720	3.861820	3.175900	34
28	0.771994	0.635629	1.543988	1.271258	2.315982	1.906887	3.087976	2.542516	3.859970	3.178145	32
30	0.771624	0.636078	1.543248	1.272156	2.314872	1.908234	3.086496	2.544312	3.858120	3.180390	30
32	0.771254	0.636527	1.542508	1.273054	2.313762	1.909581	3.085016	2.546108	3.856270	3.182635	28
34	0.770884	0.636975	1.541768	1.273950	2.312652	1.910925	3.083536	2.547900	3.854420	3.184875	26
36	0.770513	0.637424	1.541026	1.274848	2.311539	1.912272	3.082052	2.549696	3.852565	3.187120	24
38	0.770142	0.637872	1.540284	1.275744	2.310426	1.913616	3.080568	2.551488	3.850710	3.189360	22
40	0.769771	0.638320	1.539542	1.276640	2.309313	1.914960	3.079084	2.553280	3.848855	3.191600	20
42	0.769399	0.638767	1.538798	1.277534	2.308197	1.916301	3.077596	2.555068	3.846995	3.193835	18
44	0.769027	0.639215	1.538054	1.278430	2.307081	1.917645	3.076108	2.556860	3.845135	3.196075	16
46	0.768655	0.639662	1.537310	1.279324	2.305965	1.918986	3.074620	2.558648	3.843275	3.198310	14
48	0.768283	0.640109	1.536566	1.280218	2.304849	1.920327	3.073132	2.560436	3.841415	3.200545	12
50	0.767911	0.640556	1.535822	1.281112	2.303733	1.921668	3.071644	2.562224	3.839555	3.202780	10
52	0.767538	0.641003	1.535076	1.282006	2.302614	1.923009	3.070152	2.564012	3.837690	3.205015	8
54	0.767165	0.641449	1.534330	1.282898	2.301495	1.924347	3.068660	2.565796	3.835825	3.207245	6
56	0.766791	0.641895	1.533582	1.283790	2.300373	1.925685	3.067164	2.567580	3.833955	3.209475	4
58	0.766418	0.642341	1.532836	1.284682	2.299254	1.927023	3.065672	2.569364	3.832090	3.211705	2
60	0.766044	0.642787	1.532088	1.285574	2.298132	1.928361	3.064176	2.571148	3.830220	3.213935	50°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
40°	0.766044	0.642787	1.532088	1.285574	2.298132	1.928361	3.064176	2.571148	3.830220	3.213935	60′
2′	0.765670	0.643233	1.531340	1.286466	2.297010	1.929699	3.062680	2.572932	3.828350	3.216165	58
4	0.765296	0.643678	1.530592	1.287356	2.295888	1.931034	3.061184	2.574712	3.826480	3.218390	56
6	0.764921	0.644123	1.529842	1.288246	2.294763	1.932369	3.059684	2.576492	3.824605	3.220615	54
8	0.764546	0.644568	1.529092	1.289136	2.293638	1.933704	3.058184	2.578272	3.822730	3.222840	52
10	0.764171	0.645013	1.528342	1.290026	2.292513	1.935039	3.056684	2.580052	3.820855	3.225065	50
12	0.763796	0.645457	1.527592	1.290914	2.291388	1.936371	3.055184	2.581828	3.818980	3.227285	48
14	0.763420	0.645901	1.526840	1.291802	2.290260	1.937703	3.053680	2.583604	3.817100	3.229505	46
16	0.763044	0.646346	1.526088	1.292692	2.289132	1.939038	3.052176	2.585384	3.815220	3.231730	44
18	0.762668	0.646789	1.525336	1.293578	2.288004	1.940367	3.050672	2.587156	3.813340	3.233945	42
20	0.762291	0.647233	1.524582	1.294466	2.286873	1.941699	3.049164	2.588932	3.811455	3.236165	40
22	0.761915	0.647676	1.523830	1.295352	2.285745	1.943028	3.047660	2.590704	3.809575	3.238380	38
24	0.761538	0.648119	1.523076	1.296238	2.284614	1.944357	3.046152	2.592476	3.807690	3.240595	36
26	0.761161	0.648562	1.522322	1.297124	2.283483	1.945686	3.044644	2.594248	3.805805	3.242810	34
28	0.760783	0.649005	1.521566	1.298010	2.282349	1.947015	3.043132	2.596020	3.803915	3.245025	32
30	0.760406	0.649448	1.520812	1.298896	2.281218	1.948344	3.041624	2.597792	3.802030	3.247240	30
32	0.760028	0.649890	1.520056	1.299780	2.280084	1.949670	3.040112	2.599560	3.800140	3.249450	28
34	0.759649	0.650332	1.519298	1.300664	2.278947	1.950996	3.038596	2.601328	3.798245	3.251660	26
36	0.759271	0.650774	1.518542	1.301548	2.277813	1.952322	3.037084	2.603096	3.796355	3.253870	24
38	0.758892	0.651215	1.517784	1.302430	2.276676	1.953645	3.035568	2.604860	3.794460	3.256075	22
40	0.758513	0.651657	1.517026	1.303314	2.275539	1.954971	3.034052	2.606628	3.792565	3.258285	20
42	0.758134	0.652098	1.516268	1.304196	2.274402	1.956294	3.032536	2.608392	3.790670	3.260490	18
44	0.757754	0.652539	1.515508	1.305078	2.273262	1.957617	3.031016	2.610156	3.788770	3.262695	16
46	0.757375	0.652980	1.514750	1.305960	2.272125	1.958940	3.029500	2.611920	3.786875	3.264900	14
48	0.756995	0.653420	1.513990	1.306840	2.270985	1.960260	3.027980	2.613680	3.784975	3.267100	12
50	0.756614	0.653860	1.513228	1.307720	2.269842	1.961580	3.026456	2.615440	3.783070	3.269300	10
52	0.756234	0.654301	1.512468	1.308602	2.268702	1.962903	3.024936	2.617204	3.781170	3.271505	8
54	0.755853	0.654740	1.511706	1.309480	2.267559	1.964226	3.023412	2.618960	3.779265	3.273700	6
56	0.755472	0.655180	1.510944	1.310360	2.266416	1.965540	3.021888	2.620720	3.777360	3.275900	4
58	0.755091	0.655619	1.510182	1.311238	2.265273	1.966857	3.020364	2.622476	3.775455	3.278095	2
60	0.754709	0.656059	1.509418	1.312118	2.264127	1.968177	3.018836	2.624236	3.773545	3.280295	49°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
41°	0.754709	0.656059	1.509418	1.312118	2.264127	1.968177	3.018836	2.624236	3.773545	3.280295	60'
2	0.754327	0.656498	1.508654	1.312996	2.262981	1.969494	3.017308	2.625992	3.771635	3.282490	58
4	0.753945	0.656936	1.507890	1.313872	2.261835	1.970808	3.015780	2.627744	3.769725	3.284680	56
6	0.753563	0.657375	1.507126	1.314750	2.260689	1.972125	3.014252	2.629500	3.767815	3.286875	54
8	0.753180	0.657813	1.506360	1.315626	2.259540	1.973439	3.012720	2.631252	3.765900	3.289065	52
10	0.752798	0.658251	1.505596	1.316502	2.258394	1.974753	3.011192	2.633004	3.763990	3.291255	50
12	0.752414	0.658689	1.504828	1.317378	2.257242	1.976067	3.009656	2.634756	3.762070	3.293445	48
14	0.752031	0.659127	1.504062	1.318254	2.256093	1.977381	3.008124	2.636508	3.760155	3.295635	46
16	0.751648	0.659564	1.503296	1.319128	2.254944	1.978692	3.006592	2.638256	3.758240	3.297820	44
18	0.751264	0.660001	1.502528	1.320002	2.253792	1.980003	3.005056	2.640004	3.756320	3.300005	42
20	0.750880	0.660438	1.501760	1.320876	2.252640	1.981314	3.003520	2.641752	3.754400	3.302190	40
22	0.750495	0.660875	1.500990	1.321750	2.252485	1.982625	3.001980	2.643500	3.752475	3.304375	38
24	0.750111	0.661311	1.500222	1.322622	2.250333	1.983933	3.000444	2.645244	3.750555	3.306555	36
26	0.749726	0.661748	1.499452	1.323496	2.249178	1.985244	2.998904	2.646992	3.748630	3.308740	34
28	0.749341	0.662184	1.498682	1.324368	2.248023	1.986552	2.997364	2.648736	3.746705	3.310920	32
30	0.748955	0.662620	1.497910	1.325240	2.246865	1.987860	2.995820	2.650480	3.744775	3.313100	30
32	0.748570	0.663055	1.497140	1.326110	2.245710	1.989165	2.994280	2.652220	3.742850	3.315275	28
34	0.748184	0.663491	1.496368	1.326982	2.244552	1.990473	2.992736	2.653964	3.740920	3.317455	26
36	0.747798	0.663926	1.495596	1.327852	2.243394	1.991778	2.991192	2.655704	3.738990	3.319630	24
38	0.747411	0.664361	1.494822	1.328722	2.242233	1.993083	2.989644	2.657444	3.737055	3.321805	22
40	0.747025	0.664795	1.494050	1.329590	2.241075	1.994385	2.988100	2.659180	3.735125	3.323975	20
42	0.746638	0.665230	1.493276	1.330460	2.239914	1.995690	2.986552	2.660920	3.733190	3.326150	18
44	0.746251	0.665664	1.492502	1.331325	2.238753	1.996992	2.985004	2.662656	3.731255	3.328320	16
46	0.745863	0.666098	1.491726	1.332196	2.237589	1.998294	2.983452	2.664392	3.729315	3.330490	14
48	0.745476	0.666532	1.490952	1.333064	2.236428	1.999596	2.981904	2.666128	3.727380	3.332660	12
50	0.745088	0.666966	1.490176	1.333932	2.235264	2.000898	2.980352	2.667864	3.725440	3.334830	10
52	0.744699	0.667399	1.489398	1.334798	2.234097	2.002197	2.978796	2.669596	3.723495	3.336995	8
54	0.744311	0.667832	1.488622	1.335664	2.232933	2.003496	2.977244	2.671328	3.721555	3.339160	6
56	0.743922	0.668265	1.487844	1.336530	2.231766	2.004795	2.975688	2.673060	3.719610	3.341325	4
58	0.743534	0.668698	1.487068	1.337396	2.230602	2.006094	2.974136	2.674792	3.717670	3.343490	2
60	0.743144	0.669130	1.486288	1.338260	2.229432	2.007390	2.972576	2.676520	3.715720	3.345650	48°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse. 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
42°	0.743144	0.669130	1.486288	1.338260	2.229432	2.007390	2.972576	2.676520	3.715720	3.345650	60'
2'	0.742755	0.669562	1.485510	1.339124	2.228265	2.008686	2.971020	2.678248	3.713775	3.347810	58
4	0.742365	0.669994	1.484730	1.339988	2.227095	2.009982	2.969460	2.679976	3.711825	3.349970	56
6	0.741975	0.670426	1.483950	1.340852	2.225925	2.011278	2.967900	2.681704	3.709875	3.352130	54
8	0.741585	0.670858	1.483170	1.341716	2.224755	2.012574	2.966340	2.683432	3.707925	3.354290	52
10	0.741195	0.671289	1.482390	1.342578	2.223585	2.013867	2.964780	2.685156	3.705975	3.356445	50
12	0.740804	0.671720	1.481608	1.343440	2.222412	2.015160	2.963216	2.686880	3.704020	3.358600	48
14	0.740413	0.672151	1.480826	1.344302	2.221239	2.016453	2.961652	2.688604	3.702065	3.360755	46
16	0.740022	0.672582	1.480044	1.345164	2.220066	2.017746	2.960088	2.690328	3.700110	3.362910	44
18	0.739631	0.673012	1.479262	1.346024	2.218893	2.019036	2.958524	2.692048	3.698155	3.365060	42
20	0.739239	0.673442	1.478578	1.346884	2.217717	2.020326	2.956956	2.693768	3.696195	3.367210	40
22	0.738847	0.673872	1.477694	1.347744	2.216541	2.021616	2.955388	2.695488	3.694235	3.369360	38
24	0.738455	0.674302	1.476910	1.348604	2.215365	2.022906	2.953820	2.697208	3.692275	3.371510	36
26	0.738062	0.674731	1.476124	1.349462	2.214186	2.024193	2.952248	2.698924	3.690310	3.373656	34
28	0.737670	0.675161	1.475340	1.350322	2.213010	2.025483	2.950680	2.700644	3.688350	3.375806	32
30	0.737277	0.675590	1.474554	1.351180	2.211831	2.026770	2.949108	2.702360	3.686385	3.377950	30
32	0.736884	0.676019	1.473768	1.352038	2.210652	2.028057	2.947536	2.704076	3.684420	3.380095	28
34	0.736490	0.676447	1.472980	1.352894	2.209470	2.029341	2.945960	2.705788	3.682450	3.382235	26
36	0.736097	0.676876	1.472194	1.353752	2.208291	2.030628	2.944388	2.707504	3.680485	3.384380	24
38	0.735703	0.677304	1.471406	1.354608	2.207109	2.031912	2.942812	2.709216	3.678515	3.386520	22
40	0.735309	0.677732	1.470618	1.355464	2.205927	2.033196	2.941236	2.710928	3.676545	3.388660	20
42	0.734914	0.678159	1.469828	1.356318	2.204742	2.034477	2.939656	2.712636	3.674570	3.390795	18
44	0.734519	0.678587	1.469038	1.357174	2.203557	2.035761	2.938076	2.714348	3.672595	3.392935	16
46	0.734125	0.679014	1.468250	1.358028	2.202375	2.037042	2.936500	2.716056	3.670625	3.395070	14
48	0.733729	0.679441	1.467458	1.358882	2.201187	2.038323	2.934916	2.717764	3.668645	3.397205	12
50	0.733334	0.679868	1.466668	1.359736	2.200002	2.039604	2.933336	2.719472	3.666670	3.399340	10
52	0.732938	0.680294	1.465876	1.360588	2.198814	2.040882	2.931752	2.721176	3.664690	3.401470	8
54	0.732542	0.680720	1.465084	1.361440	2.197626	2.042160	2.930168	2.722880	3.662710	3.403600	6
56	0.732146	0.681146	1.464292	1.362292	2.196438	2.043438	2.928584	2.724584	3.660730	3.405730	4
58	0.731750	0.681572	1.463500	1.363144	2.195250	2.044716	2.927000	2.726288	3.658750	3.407860	2
60	0.731353	0.681998	1.462706	1.363996	2.194059	2.045994	2.925412	2.727992	3.656765	3.409990	47°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
43°	0.731353	0.681998	1.462706	1.363996	2.194059	2.045994	2.925412	2.727992	3.656765	3.409990	60′
2	0.730956	0.682423	1.461912	1.364846	2.192868	2.047269	2.923824	2.729692	3.654780	3.412115	58
4	0.730559	0.682848	1.461118	1.365696	2.191677	2.048544	2.922236	2.731392	3.652795	3.414240	56
6	0.730162	0.683273	1.460324	1.366546	2.190486	2.049819	2.920648	2.733092	3.650810	3.416365	54
8	0.729764	0.683698	1.459528	1.367396	2.189292	2.051094	2.919056	2.734792	3.648820	3.418490	52
10	0.729366	0.684122	1.458732	1.368244	2.188098	2.052366	2.917464	2.736488	3.646830	3.420610	50
12	0.728968	0.684547	1.457936	1.369094	2.186904	2.053641	2.915872	2.738188	3.644840	3.422735	48
14	0.728570	0.684971	1.457140	1.369942	2.185710	2.054913	2.914280	2.739884	3.642850	3.424855	46
16	0.728171	0.685394	1.456342	1.370788	2.184513	2.056182	2.912684	2.741576	3.640855	3.426970	44
18	0.727772	0.685818	1.455544	1.371636	2.183316	2.057454	2.911088	2.743272	3.638860	3.429090	42
20	0.727373	0.686241	1.454746	1.372482	2.182119	2.058723	2.909492	2.744964	3.636865	3.431205	40
22	0.726974	0.686664	1.453948	1.373328	2.180912	2.059992	2.907896	2.746656	3.634870	3.433320	38
24	0.726574	0.687087	1.453148	1.374174	2.179722	2.061261	2.906296	2.748348	3.632870	3.435435	36
26	0.726174	0.687510	1.452348	1.375020	2.178522	2.062530	2.904696	2.750040	3.630870	3.437550	34
28	0.725774	0.687932	1.451548	1.375864	2.177322	2.063796	2.903096	2.751728	3.628870	3.439660	32
30	0.725374	0.688354	1.450748	1.376708	2.176122	2.065062	2.901496	2.753416	3.626870	3.441770	30
32	0.724973	0.688776	1.449946	1.377552	2.174919	2.066328	2.899892	2.755104	3.624865	3.443880	28
34	0.724572	0.689198	1.449144	1.378396	2.173716	2.067594	2.898288	2.756792	3.622860	3.445990	26
36	0.724171	0.689619	1.448342	1.379238	2.172513	2.068857	2.896684	2.758476	3.620855	3.448095	24
38	0.723770	0.690040	1.447540	1.380080	2.171310	2.070120	2.895080	2.760160	3.618850	3.450200	22
40	0.723369	0.690461	1.446738	1.380922	2.170107	2.071383	2.893476	2.761844	3.616845	3.452305	20
42	0.722967	0.690882	1.445934	1.381764	2.168901	2.072646	2.891868	2.763528	3.614835	3.454410	18
44	0.722565	0.691302	1.445130	1.382604	2.167695	2.073906	2.890260	2.765208	3.612825	3.456510	16
46	0.722162	0.691723	1.444324	1.383446	2.166486	2.075169	2.888648	2.766892	3.610810	3.458615	14
48	0.721760	0.692143	1.443520	1.384286	2.165280	2.076429	2.887040	2.768572	3.608800	3.460715	12
50	0.721357	0.692563	1.442714	1.385126	2.164071	2.077689	2.885428	2.770252	3.606785	3.462815	10
52	0.720954	0.692982	1.441908	1.385964	2.162862	2.078946	2.883816	2.771928	3.604770	3.464910	8
54	0.720551	0.693401	1.441102	1.386802	2.161653	2.080203	2.882204	2.773604	3.602755	3.467005	6
56	0.720147	0.693820	1.440294	1.387640	2.160441	2.081460	2.880588	2.775280	3.600735	3.469100	4
58	0.719743	0.694239	1.439486	1.388478	2.159229	2.082717	2.878972	2.776956	3.598715	3.471195	2
60	0.719339	0.694658	1.438678	1.389316	2.158017	2.083974	2.877356	2.778632	3.596695	3.473290	46°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		
	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	
44°	0.719339	0.694658	1.438678	1.389316	2.158017	2.083974	2.877356	2.778632	3.596695	3.473290	60′
2′	0.718935	0.695076	1.437870	1.390152	2.156805	2.085228	2.875740	2.780304	3.594675	3.475380	58
4	0.718531	0.695494	1.437062	1.390988	2.155593	2.086482	2.874124	2.781976	3.592655	3.477470	56
6	0.718126	0.695912	1.436252	1.391824	2.154378	2.087736	2.872504	2.783648	3.590630	3.479560	54
8	0.717721	0.696330	1.435442	1.392660	2.153163	2.088990	2.870884	2.785320	3.588605	3.481650	52
10	0.717316	0.696747	1.434632	1.393494	2.151948	2.090241	2.869264	2.786988	3.586580	3.483735	50
12	0.716910	0.697165	1.433820	1.394330	2.150730	2.091495	2.867640	2.788660	3.584550	3.485825	48
14	0.716504	0.697582	1.433008	1.395164	2.149512	2.092746	2.866016	2.790328	3.582520	3.487910	46
16	0.716098	0.697998	1.432196	1.395996	2.148294	2.093994	2.864392	2.791992	3.580490	3.489990	44
18	0.715692	0.698415	1.431384	1.396830	2.147076	2.095245	2.862768	2.793660	3.578460	3.492075	42
20	0.715286	0.698831	1.430572	1.397662	2.145858	2.096493	2.861144	2.795324	3.576430	3.494155	40
22	0.714879	0.699247	1.429758	1.398494	2.144637	2.097741	2.859516	2.796988	3.574395	3.496235	38
24	0.714472	0.699663	1.428944	1.399326	2.143416	2.098989	2.857888	2.798652	3.572360	3.498315	36
26	0.714065	0.700078	1.428130	1.400156	2.142195	2.100234	2.856260	2.800312	3.570325	3.500390	34
28	0.713658	0.700494	1.427316	1.400988	2.140974	2.101482	2.854632	2.801976	3.568290	3.502470	32
30	0.713250	0.700909	1.426500	1.401818	2.139750	2.102727	2.853000	2.803636	3.566250	3.504545	30
32	0.712842	0.701324	1.425684	1.402648	2.138526	2.103972	2.851368	2.805296	3.564210	3.506620	28
34	0.712434	0.701738	1.424868	1.403476	2.137302	2.105214	2.849736	2.806952	3.562170	3.508690	26
36	0.712026	0.702153	1.424052	1.404306	2.136078	2.106459	2.848104	2.808612	3.560130	3.510765	24
38	0.711617	0.702567	1.423234	1.405134	2.134851	2.107701	2.846468	2.810268	3.558085	3.512835	22
40	0.711208	0.702981	1.422416	1.405962	2.133624	2.108943	2.844832	2.811924	3.556040	3.514905	20
42	0.710799	0.703394	1.421598	1.406788	2.132397	2.110182	2.843196	2.813576	3.553995	3.516970	18
44	0.710390	0.703808	1.420780	1.407616	2.131170	2.111424	2.841560	2.815232	3.551950	3.519040	16
46	0.709980	0.704221	1.419960	1.408442	2.129940	2.112663	2.839920	2.816884	3.549900	3.521105	14
48	0.709570	0.704634	1.419140	1.409268	2.128710	2.113902	2.838280	2.818536	3.547850	3.523170	12
50	0.709160	0.705046	1.418320	1.410092	2.127480	2.115133	2.836640	2.820184	3.545800	3.525230	10
52	0.708750	0.705459	1.417500	1.410918	2.126250	2.116377	2.835000	2.821836	3.543750	3.527295	8
54	0.708339	0.705871	1.416678	1.411742	2.125017	2.117613	2.833356	2.823484	3.541695	3.529355	6
56	0.707929	0.706283	1.415858	1.412566	2.123787	2.118849	2.831716	2.825132	3.539645	3.531415	4
58	0.707518	0.706695	1.415036	1.413390	2.122554	2.120085	2.830072	2.826780	3.537590	3.533475	2
60	0.707106	0.707106	1.414212	1.414212	2.121318	2.121318	2.828424	2.828424	3.535530	3.535530	45°
	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Distance from Planes of Meridian, or East or West Distance.	Distance from Planes of Latitude, or North or South Distance.	Degrees and Minutes.
	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.		Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.		Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.		Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.		Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.		

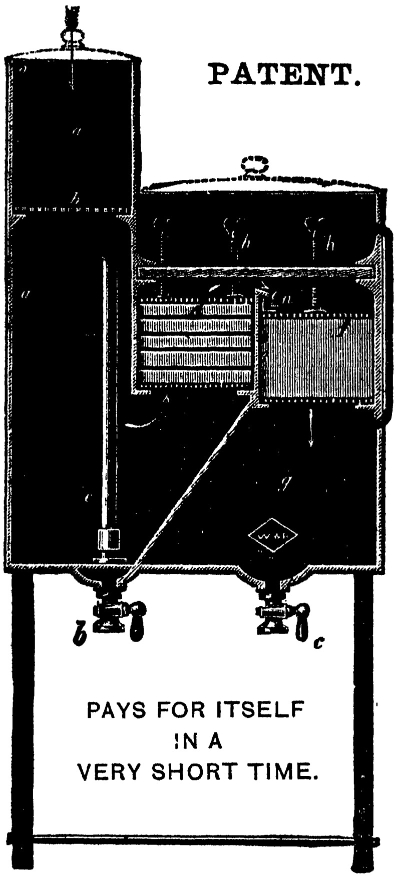
INDEX.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.

EVERY ENGINE ROOM

should have a

"DIAMOND" WASTE OIL FILTER,



For Purifying Refuse Oil and Grease,

AS USED BY THE

L. & N. W. Railway Co.
Midland Do.
Gt. Northern Do.
Gt. Western Do.
Lancs. & Yorks. Do.
L. B. & S. C. Do.
Central Argentine Do.
Aktiebolaget Elektron.
India Rubber, Gutta Percha, &c., Co.
Jones, Burton, & Co.
Bratsberg Copper Smelting Co.
De Beers Diamond Mines.
Burma Ruby Do.
J. M. Sumner & Co.
Felber, Jucker, & Co.
International Cotton Waste Co.
Elmore Copper Depositing Co., Ld.
Brunner, Mond, & Co., Ld.

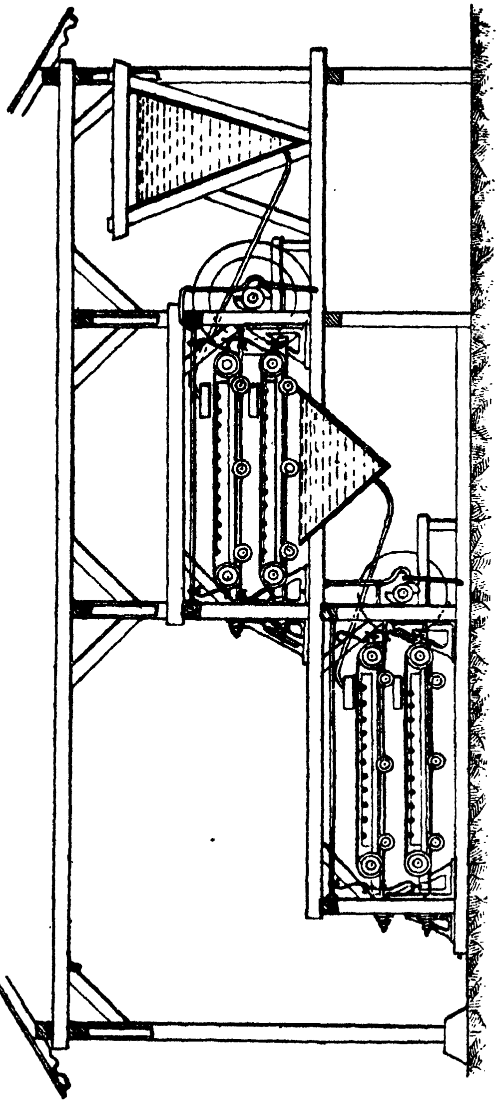
And others too numerous to mention.

WOODHOUSE & RAWSON UNITED,

Electrical, M

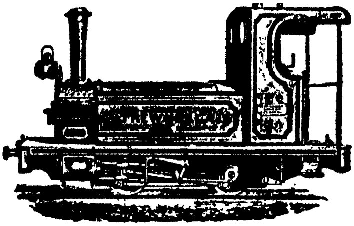
88, QUEEN VICTORIA STREET, LONDON, E.C.,

And JOHANNESBURG, SYDNEY and MELBOURNE



THE LUHRIG COMPOUND VANNER, ORE CONCENTRATOR & SEPARATOR.

Portable and Permanent Railways and Rolling Stock for Mining.



Winding Engine and Pit-head Gear, Ropes Pulleys, Cages, &c.

KERR, STUART, & CO.

20, BUCKLERSBURY,

LONDON, E.C.

CATALOGUES & ESTIMATES FREE ON APPLICATION.